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SCALES OF SEEING.*

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When it is reported that the seeing at a locality is good or bad, we have gained no precise information in regard to the atmosphere unless we thoroughly know the place referred to or perfectly acquainted with the observer who makes the statement and his class of work. When we see the record of an observation accompanied by a numerical note of the seeing as if to confirm its validity, we are apt to forget that such an addition may give little confirmation to the minds of other astronomers because in most cases the quality of the seeing is judged from the objects seen and then the figure is quoted to confirm them; it is simply arguing in a circle. The seeing as usually quoted is merely an indication of the confidence the observer has in his own work. Everyone knows that suspicion may become certainty through improved seeing and that the true quality of the seeing is a weight which can be assigned to the observation and enable others to judge of its value; but when each observer quotes his own arbitrary scale, such weighting is nearly worthless. In order to convey information the seeing has to be described minutely, or referred to a standard scale.

In almost every case the scale of seeing is confessedly derived from the observer's experience, and as the average range of seeing to which he has become accustomed is dependent upon his latitude, the nearness of mountains or oceans, presence of snow, elevation above sea level, upon the character of the work undertaken, the average altitude of the celestial body above the horizon

* Second paper on the subject of Atmosphere and Observatory Sites. The first paper entitled, "Atmosphere, Telescope and Observer," appeared in POPULAR ASTRONOMY for June 1897. The present paper was almost completed in July of that year but owing to my absence from the Observatory and the loss by fire of Mr. Drew's observations on seeing at different zenith distances and comparisons of aperture, it has had to wait for me to make a new set of observations.

As observed at Jeur, India, by Lick Observatory Eclipse Expedition.

and upon the aperture of the lens, his scale is not likely to be general in any sense. For these reasons I advocate in this paper the use of a standard scale of seeing and give some of its variations under certain conditions of aperture and zenith distance.

The Standard Scale.

The standard stellar scale is due to Professor W. H. Pickering who completed it in nearly its present form at Arequipa in 1891.

Under date of December 9 of that year the following was published in the *Nachrichten* No. 3079, (his scale numbers 3, 4 and 5 have been changed to 6, 8 and 10 and other slight alterations made):

"Under good conditions the brighter stars are surrounded with numerous diffraction rings:—

Seeing 6 indicates that the rings are broken and impossible to count.
Seeing 8 indicates that although in motion, the rings are complete and may be counted and that the central point of light is readily separable from the inner ring.
Seeing 10 indicates that each ring is perfect and immovable."

This scale was derived from the use of a 13-inch instrument. It was given to me in a more complete form when I first went to Arizona to test proposed sites for the Observatory. Later on, and now nearly four years ago, but after it was discovered that the seeing on Mars was not the same for micrometer measurement as for drawing detail, it was proposed to adopt a scale of seeing which would include two figures in every case, one in regard to the steadiness of the limb and the other depending on the amount of detail. This was, in fact, in use for some time and from that very use suggested a still more detailed method of recording the seeing which consisted in the record of many figures each one describing the amplitude of some vibration exhibited by the planet. This is undoubtedly the most perfect form of recording the seeing but it is very difficult and can hardly be made practical as yet. The most important motions were those called "total confusion" and "bodily motion." The first was the width through which the limb was indeterminate; it measured the extinction of fine detail. The other was the swaying motion of the whole planet in the field; which is a decided obstacle in good micrometer work. This is essentially the same as the limb and detail method but in this case the figures represented direct estimates of the amount of these two motions expressed in tenths of seconds of arc. The objection to both of these methods is their complication, and to the latter, the necessity for having a measuring instrument and a long focus telescope and high power.

The standard scale here adopted, depends upon the perfection of the image of any bright star as seen in a telescope of six-inch aperture, apart from any defects caused by the lens or its adjustment. In making the observation the name of the star should be recorded, and also its zenith distance and brightness; its brightness however is really of little importance except that if a star is faint it is harder to judge of the seeing by it; there is no difference in the figure of the seeing. But the zenith distance is almost as important as the seeing itself because the seeing varies rapidly with this distance.

STANDARD SCALE OF SEEING.

0. Disk and rings in one confused mass, violent motion, image greatly enlarged (for example to twice the diameter of the third ring) and varying in size.
2. Disk and rings in one confused mass, constant motion, no increase in size.
4. Disk well defined, no evidence of rings.
6. Disk well defined, rings broken into dots and lines but still traceable.
8. Disk well defined, rings complete but moving.
10. Disk well defined, rings motionless.

With each number should be given the average amount of bodily motion, thus indicating the effect of air waves too large to otherwise affect the form of the stellar image in a 6-inch telescope.

I anticipate that in most countries this standard scale will be found satisfactory in use. In my own experience in regions of comparatively good seeing, numbers 0, 2 and 4 are the most readily distinguished, that is, the most constant in a given observation for seeing. Numbers 4, 6, 8 and 10 are apt to change quickly from one to another. On perhaps the majority of occasions the seeing has included 4, 6 and 8 and the final figure must be obtained from the proportionate amount of these. The seeing is best expressed by recording the observed amount of each, which shows at once what instants of good seeing are likely to be obtained. For practical purposes one should at least be able to obtain from the record both the range and the mean value. In order to get a satisfactory idea of the seeing it is well to make quite a number of records at short intervals so that the mean will be tolerably exact. It is by no means necessary to strive for great exactness in each estimate. The seeing (in our experience) varies considerably in long intervals, from ten minutes to several hours. A little experience will show how far such changes are likely to restrict the application of the recorded figure.

There are rare cases more easily predicted from theory than from experience for which the mere record of the form of the stellar image is wholly inadequate; in such cases a record of the mo-

tions of the image is essential. They arise from the use of very big lenses. Throughout the observations which I have made upon the currents in the atmosphere, in instruments of 18 and 24 inches, the maximum distance from crest to crest, so to speak, of the air waves has been about five inches. So that waves up to nearly this size seen in either large or small glasses will not be too large for a six-inch aperture and will affect the appearance of the image.

Nevertheless waves larger than six inches sometimes exist and doubtless usually have escaped notice because when the waves reach a size equal to one-third or one-half the diameter of the lens they become difficult to see. So with different combination of waves, the following results will be noticed: With merely a set of waves of less than six inches, the confusion and loss of planetary detail will be similar in a 6-inch and, let us say, a 30-inch telescope; a star-image will have form 2 without bodily motion in a 30-inch and any form from 2 up, in a 6-inch depending on the actual size of the waves. If the waves are above one and one-half inches there will probably be some bodily motion; the planetary detail also will improve with coarser waves.

As the waves increase from six to thirty inches there will be no change in the amount of detail seen in a six inch lens but both the detail and the stellar image will steadily improve in a 30-inch. But the stellar image in the 6-inch will have merely a bodily motion and will show no change while the waves are becoming coarser and will therefore fail to indicate these changes which are of great importance to the large lens. For this reason the bodily motion should always be recorded when the seeing is above 7 in the standard 6-inch lens. Most unfortunately for astronomers these coarse waves are very rare and when they do occur their good qualities are rendered useless by the presence of sets of fine waves which spoil the seeing.

The practical use in knowing of their presence is that when they do exist diaphragms may be advantageous on large instruments, because if the coarse waves are not too much smaller than the large lens, a large aperture diaphragm may remove their bad effects upon fine detail without greatly reducing the light. The best indication of their presence is a perfect image showing large bodily motion or a twinkling of the disk in a 6-inch telescope. A flowing over of the central disk onto the rings is probably another indication of them.

EFFECT OF DIFFERENT APERTURES ON THE STANDARD SCALE.

On applying Pickering's scale for a 13-inch telescope continu-

ously to a 6-inch telescope, early in 1894, I found that the gradations of the form of the Image I saw, were somewhat different. In the scale given above for a 13-inch (the scale which Professor Pickering handed me for use in Arizona) the confusion of the disk with the inner ring supplies the distinction between 6 and 8, but in the 6-inch which I had with me the disk ceased to be confused with the rings before the rings themselves became distinguishable, and this has been the almost constant experience since. Once or twice, late in the afternoon when the seeing was about to become exceptionally good I have seen the rings finely distinct in the 6-inch, and the disc now and then suddenly extend itself in some direction over upon them. If we find that this usually is associated with good seeing, it will be very important to hunt out all the places in the world where it occurs.

But while the perfection or universality of the scale may possibly be affected by certain changes in the character of the atmospheric currents it certainly does change markedly with alteration in the aperture of the lens. Not only is the figure denoting the seeing different but the very scale itself is altered. I was forced to this conclusion by observing that in an 18-inch, the pure form 4 on the 6-inch scale never occurred and that 6 was very rare; the seeing usually jumped from 2 to 8 or 8 to 2, while in the 24-inch the denoting of gradations by the state of the rings is almost impossible.

Below may be found a summary of the actual observations on comparison of scales and apertures. In parallel columns the corresponding figure in each scale for a given condition of the air is indicated by being on the same horizontal line. This is somewhat uncertain with regard to the 13-inch and the 18-inch but in the other cases is the mean result of direct comparisons.

The numbers in parentheses at the right of the seeing number indicates the number of direct comparisons with the 6-inch.

Eye. ¼-inch	1.6-inch	4-inch	6-inch	13-inch	18-inch	24-inch
1.7 (4) 33 twinkles in 10 sec.	7 (2) Disk well defined, rings not quite complete.	0 to 2 See paragraph foll. table.	0.0 Enlarged Mass	0 Enlarged mass	0 Enlarged mass	0 Enlarged mass
2.6 (6) 26 twink. in 10 sec.	9 (2) Image complete, rings not perfectly quiet.	3	1.0 Enlarging Mass	1 Enlarging mass	0	0
3.6 (4) 19 twink. in 10 sec.	9.4 (3) Perfect and rings nearly quiet.	3.8 (1) Bad. Mot. 7 .9	2.0	2	1	0

TABLE CONTINUED.

Eye. ¼-inch	1.6-1nch	4-inch	6-inch	13-inch	18-inch	24-inch
4.5 (4) 15 twink. in 10 sec.	10 (1) Image now shows only bodily motion no relative motion in its parts.	4.7 (1) Bod. Mot. 4″.0	3.0 Centralized Mass	3 Centralized mass	1	1 Enlarging mass
5.4 (7) 12 twink. in 10 sec.	10 (2)	5.6 (2) Bod. Mot. 2″.5	4.0 Disk perfect; rings confused	3	2 Confused mass	1
6.4 (9) 9 twink. in 10 sec.	10 (2)	6.3 (2) Bod. Mot. 1″.8	5.0 Disk perfect, rings rudimentary	3 and 5 Centralized mass, rings rudimentary	3 Centralized mass	2 Confused mass
7.2 (10) 6 twink. in 10 sec.	10 (2)	7.2 (1) Bod. Mot. 1″.3	6.0 Disk perfect, rings traceable	3 to 4, and 6 Disk traceable, rings traceable.	3 and 5 Centralized mass, rings rudimentary	2 to 3 (3) Rare centralization.
8.2 (11) 3 twink. in 10 sec.	10 (4)	8.0 (4) Bod. Mot. 1″.1	7.0 Disk perfect, rings not quite complete	3 to 4, and 6	3 to 4, and 6 Disk traceable, rings tracable.	2, 3 and 5 (3) Some centralization, rings rudimentary.
9.0 (2) 1 twink. in 10 sec.	10 (1)	8.8 (1) Bod. Mot. 1″.0	8.0 Disk perfect, rings complete but moving.	3 to 4, and 7 Disk traceable, rings not quite complete.	3 to 4, and 6	3 and 5 Centralized mass, rings rudimentary.
9.5 ½ twink. in 10 sec.	10	9.3	9.0 Disk perfect, rings complete and nearly quiet.	8 Disk perfect, rings complete but moving.	3 to 4, and 7 Disk traceable, rings not quite complete.	3 and 6 (1) Strong centralization, rings traceable.
10 No twink. in 10 sec.	10	10	10.0 Image perfect, no relative motion of parts.	9 and 10 Image perfect, little or no relative motion of parts.	8 and 10 Image more or less perfect, decreasing motion of parts.	4 to 10, 7 to 10 Image improving until perfect.

The columns above give the comparison of apertures reduced to uniformity; the actual results were plotted on squared paper and the values of the mean continuous curve were entered in the table. The only alterations from the observed values of any importance occur in the columns for the eye and the 4-inch; in fact these were the only ones that required actual plotting to get the mean values. The observed values for these apertures were as follows:

6-inch.	Eye.	4-inch.			
0.0	1.5				
1.0	2.5				″
2.0	4.0	3	Bodily	Motion	7.9
3.0	4.5	5	″	″	3.4
4.0	4.7	6.0	″	″	2.8
5.0	6.4	6.5	″	″	2.2
6.0	7.8	7	″	″	1.1
7.0	8.2	7.8	″	″	1.5
8.0	8.5	9	″	″	0.9
9.0					
10.0					

The differences between these scales are described in more detail in the following paragraphs, and the causes of many of them are explained. The differences occur in the form of this image, the amount and velocity of its motions and its variations in brilliancy, or twinkling.

First, in regard to the form of the image. In a small telescope, as the seeing improves, the confused mass quickly becomes centralized and the disk appears distinct and separate from the constantly moving globules surrounding it. From these the rings subsequently emerge, first showing rudiments, then traceable, finally complete though still in motion. With a large aperture the centralization is not so rapid. In the confused moving mass rudiments of ring begin to float around a slightly brighter center. The center grows brighter and the rings become traceable but the disk does not appear until the rings are complete though still moving.

This difference I explain in the following way. The disk is illuminated by the whole lens, whether large or small; consequently in the case of a large lens, compared with which the "waves" in the air are sure to be small, the lens becomes divided, as it were, into many pieces and the disk becomes split up, distorted, refracted, that is, misplaced, and probably enlarged. So with a big lense the state of the air has to be very much better than with a small one for centralization or disk to become evident. But in the case of the rings, a portion of a ring large enough to be called a rudiment or even if it is so large that the ring may be called traceable, receives light from only a certain proportion of the lens. So as we change from a small to a large lens the increase of area illuminating the portion of the ring is not so great as that illuminating the disk, and therefore the portion of ring is by that much less likely to be split up into smaller pieces, distorted, refracted or enlarged by the air waves. With an aperture therefore very large in proportion to the mean size of the currents the rings, as the seeing improves, must begin to form before the disk tends to separate from them.

This theory explains why it happens that in a lens much larger than the atmospheric waves the rings begin to form before the disk but it does not explain why, when the lens is the same size as or little larger than the waves, the disk actually forms before the rings become rudimentary. I think this must be due to some relation between the angular size of the disk and the mean refractive power of the waves.

It is almost needless to add that this difference between apertures was discovered in 1894 but the explanation has been worked out only for the present paper.

Quantitative Relation Between Size of Waves, Aperture and Form of Stellar Image.

From observations begun in September 1894 I can go even into the quantitative relation between size of waves, aperture and scale. Atmospheric waves smaller than two-thirds of an inch or larger than four inches are very rare. Of those between these limits there is almost always present a set of waves over one inch apart; they are almost free from noticeable variations throughout considerable intervals in a given evening, if not for the whole night. There is usually also a very variable set of waves of less than one inch in size; they appear and disappear, come in sheets like the rippled surface of falling water, or they come slowly, with twists and turns and squirming. When the latter are visible and conspicuous they divide the lens into many minute elements and destroy the character of the image in the 24-inch and 6-inch but they have very little if any effect on the 1.6-inch. When these fine waves are absent or faint the spurious disk in the 6-inch may become good, but I never have seen it good in the 24-inch although the rings become quite traceable. I therefore draw the conclusion that when the waves are roughly greater than one-half of the lens in size they have little or no effect on the image; when they are less than one-half they begin to destroy the disk and when they are one-sixth or one-eighth or less they destroy the rings. The amount of damage to disk and rings is always of course directly proportioned to their conspicuousness; if they are sufficiently faint they may have no effect.

The measures of bodily motion in the 6-inch, 4 inch and 1.6-inch, tabulated on a subsequent page, show about the same motion in the smaller instrument for the same condition of the air, which is contrary to the theory explained in a former paper. This may be due to error of measurement because the motions were estimated by comparisons with the spurious disk whose diameter is inversely proportional to the aperture (but I suspect not the same in a very long focus)* and whose linear motions are proportioned to the focal length. Therefore with a small telescope its size is increased, while its motion apparently becomes less. So on turning from a larger instrument one is liable to underestimate the amount of vibration.

It is possible, however, that this is not a complete explanation.

* A micrometric investigation of this subject will be published in a subsequent paper. From measures thus far made it appears that when the focus is extremely long in comparison with the aperture, the dimensions of the diffraction pattern agrees much more closely with theory (see Encyclopædia Brittanica, *subject*, Wave Theory) than in the usual ratio of focal length and aperture, for which Dawes' results, quoted in Young's Astronomy, are sufficiently accurate.

It is probable that the theory itself should be amplified and made to read in this way: Where the lens is very large in comparison with the atmospheric waves reducing the aperture will decrease the total confusion of detail ,improve a stellar image and increase the bodily motion: but when the lens is only four or five times the size of the waves, reduction of aperture will probably decrease the confusion of detail, will certainly improve a stellar image but will have no marked effect on the bodily motions.

The motions in the smaller instrument are much slower than in the large. The explanation, which I have verified by trying the effect of diaphragms on the 24-inch telescope, is that the rapid dancing motion seen in the six-inch consists of a large slow motion with a very rapid vibratory motion superposed on it, giving a general effect of rapid motion, and that the latter is too fine to be visible in the small aperture and short focus of the little telescope.

Another difference is that the image from the smaller apertures is very apt to twinkle. At its worst the field is full of light and together with the image twinkles violently. As the seeing improves the disc first becomes steady—this is because it receives light from a greater area than equivalent portions of the rings, and the greater the area the less the twinkling as explained in a former publication on this subject early in 1895—and then the rings cease their changes of brilliancy and finally the field becomes quiet. The field light seems to be due to some certain state of air, for on some nights it is not visible in the 1.6-inch at any altitude and at other times it may even be seen in the 24-inch at low altitudes. It is very likely due to some fine current of great refractive power or to haze.

One more scale is mentioned above and therefore should receive notice here. It is the scale of twinkling. In forming this scale in practice, I first observed the extremes and then gradually applied numbers from 1 to 9 to be intermediate variations. Finally I applied Dr. See's admirable idea of counting the number of "twinkles" in ten seconds. I found that on my scale previously formed the following numbers represented the average:

Twinkling.	Seeing.	Average Number of Twinkles.	
		Observed.	Adopted.
0	10		
1	9	1	1
2	8	4	4
3	7	8	7
4	6	8	10
5	5		13
6	4	14	17
7	3	23	23
8	2	30	30
9	1		40
10	0		

In the above table the number of twinkles includes both big and little. The small ones were estimated to be a loss of 5 to 15% of light and the big ones, from 20 to 70% and sometimes also a seeming complete disappearance. Only very bright stars should be used in estimating the twinkling as its violence seems much reduced on fainter stars on account of the greater difficulty in observing the smaller absolute changes. And in estimating the character of the night stars in the zenith only should be observed.

It will be noticed that the figures in the naked eye scale derived from the twinkling of stars, are almost exactly the same as those in the 4-inch telescope for the same condition of the air in the line of sight. It may be stated in general that if at any time a naked eye scale is formed independently and developed by practice, the aperture of a telescope which will give the same figure for the seeing under normal variations of seeing as found on the naked eye scale, may be taken as a quantitative measure of the average seeing at that place.

The researches which I have made upon this subject of atmospheric waves in the last four years enable me to summarize approximately the relation between aperture and seeing, or character of a stellar image, as follows:

Waves must be at least twice the diameter of the lens to produce twinkling.

Waves larger than the lens, down to $\frac{1}{3}$ of lens	produce bodily motion,	do not destroy disk,	do not destroy rings.
Waves $\frac{1}{3}$ to $\frac{1}{5}$ of lens	produce bodily motion,	destroy disk (but less so as the angular size of the disk is increased),	do not destroy rings.
Waves $\frac{1}{5}$ to $\frac{1}{8}$ of lens	do not produce bodily motion,	destroy disk,	do not destroy rings.
Waves less than $\frac{1}{8}$ of lens	do not produce bodily motion,	destroy disk,	destroy rings.

The visibility of fine planetary detail is more or less coexistant with the disk and rings.

Expressed in another way the above table becomes as follows:

Twinkling ceases when the waves become as small as twice the diameter of the lens; the disk is lost with waves one-third the size of the lens, or smaller; bodily motion is lost when the waves get as small as one-fifth of the lens and the rings disappear when the waves are one-eighth or smaller. The amount of destruction to the disk and rings depends always on the conspicuousness, that is, the refractive power of the waves.

The Dependence of Seeing on Zenith Distance.

In March and April 1894, I made tests of the atmosphere at different points in Arizona varying in elevation above sea level

from 1100 to 8200 feet. The observations were 186 in number, 134 of these being means of ten readings; the means below include eighty-seven measures made at Tombstone, Tucson or Tempe, near Phoenix, at altitudes respectively of 4630, 2770 and 1360 feet, on eleven nights in all; twenty-nine, made at Prescott in three nights and sixty-one made at Flagstaff on twenty-one nights. The two latter were from elevations of 5700 and 6900 to 8200 feet respectively.

OBSERVATIONS IN 1894.

11 nights. 2700 feet. Mean elevation.			3 nights. 5700 feet. Mean elevation.			21 nights. 7400 feet Mean elevation.		
Z. D.	Seeing.	No. Obs'ns	Z. D.	Seeing.	No Obs'ns.	Z. D.	Seeing.	No. Obs'ns.
16	7.3	7	14	6.4	4	19	6.1	3
24	6.1	40	23	5.8	6	25	6.6	33
34	5.8	18	33	6.0	10	32	7.2	12
44	5.9	10	45	6.2	4	43	6.1	7
53	4.9	7	55	2.0	3	55	7.5	2
64	4.6	5	60	4.1	2	64	6.0	4

Upon plotting these curves and comparing them with the normal Flagstaff curve given below, it will appear that the curve for the lowest elevation is, so far as it goes, almost identical with the normal, save that it begins at the zenith at about 6.7 instead of 7.0. This difference in favor of Flagstaff is probably too small since the normal curve was made in November, December and January, months usually worse than March and April the time of observation in southern Arizona. The normal curve therefore probably should begin at a point somewhat higher on the scale than 7.0. The observations made at Flagstaff in 1894 will do this if the poorer observations are discarded, the poorer observations being those in which the least range of zenith distance was observed. This correction brings the zenith seeing at Flagstaff up to 7.5 at closely the same season of the year when it was about 6.7 at Tombstone, Tucson and Tempe, and about 5.8 at Prescott.

The curve for Prescott is of a different character. The fact that the general seeing was poorer was easily explained as being due to the Bradshaw Mountains to the south and west of the city, and will be more fully discussed in a subsequent paper. But the average seeing was nearly constant out to zenith distance 45° and then fell off very rapidly.

In November and December, 1897, and in January of 1898, one or more series of observations was made on eighteen different

nights usually for the special purpose of measuring the dependence of seeing on zenith distance. The results therefore are harmonious and instructive.

Upon constructing a curve for each night on which the series was sufficiently complete, three distinct types of curve appeared. In the first the seeing falls off at once on leaving the zenith; its decrease is almost proportional to the angular zenith distance. Such a curve was in one case obtained when the sky was covered with haze. The second type, which I call the normal, descends from, say, 8 to 7 in the first 30° and from 7 to 5 in the second. The third type shows no deterioration in seeing out to 45° or 50° and sometimes to about 70°, and then drops very rapidly. This I call the Prescott curve because it is precisely like the curve obtained there in 1894. It seems to have occurred chiefly when the atmospheric waves were especially coarse and conspicuous.

The whole collection of over one hundred and fifty complete estimates of seeing has also been arranged with reference to the value of seeing at the zenith for each night, or for each known alteration in the local conditions. It appears that the mean curve is of the same general form when the zenith seeing is 8, 7, 6, 5 and 2. Observations were made on one evening in the valley below the observatory where the zenith seeing was 0. In the tables below the means of all the observations in the 6-inch at the observatory are given, together with the results when the zenith seeing for the 6-inch was 0 and the means for the 4-inch. The mean vibratory motion of the image is given also both for the 6-inch and 4-inch, and finally the mean bodily motion of the image for each point on the 6-inch scale of seeing in each telescope and in the 1.6-inch finder. The values for the latter are somewhat uncertain owing to the difficulties of observation before mentioned.

6-inch observed means.				Continuous curve derived from preceding.		
Z. D.	Seeing.	Motion. ″	No. Obs'ns.	Z. D.	Seeing.	Motion. ″
6	7.6	1.0	11	0	7.0	1.0
14	6.8	1.1	12	10	6.9	1.1
25	6.0	1.5	9	20	6.7	1.3
35	6.2	1.4	13	30	6.4	1.4
44	6.0	1.9	17	40	6.1	1.6
55	5.6	1.6	15	50	5.7	1.8
65	4.5	2.5	17	60	5.1	2.2
74	3.6	4.4	14	70	4.2	3.5
83	1.2	6.5	17	80	2.2	5.7
				8.5	0.0	7.2

6-inch; observed zenith seeing 0.					4-inch; observed means.			
Z. D.	Seeing.	Remarks.	Motion.	No. Obs'ns.	Z. D.	Seeing.	Motion.	No. Obs'ns.
			"				"	
6	0	halo	3.8	1	5	7.5	1.5	3
					12	7.3	0.9	3
22	0	halo	4.5	2	20			
30	1.		5.2	1	34	6.8	1.1	4
45	—1	field hazy	6.8	1	46	6.6	1.2	4
58	0—		5.2	1	54	6.2	1.8	3
68	—1	halo and field full of light	7.5	1	62	6.0	1.7	1
					74	2.8	4.5	4
					82	1.5	6.8	2

SEEING AND BODILY MOTION.

Seeing in 6-inch.	Motion in 6 inch.			4-inch.			1.6-inch.		
	Obs'd Means	No. Obs'ns	Derived Means	Obs'd Means	No. Obsn's	Derived Means	Obs'd Means	No. Obsn's	Derived Means
	"		"	"		"	"		"
0	8.8	9	8.8	7.9	2	7.9	4.2	2	4.7(?)
1	5.9	9	6.2	4.8	6	5.3	3.2	2	4.7(?)
2	4.6	15	4.5	6.4	3	3.7	4.7	3	4.7
3	3.0	7	3.2	3.4	4	2.5	3.4	1	3.5
4	2.2	17	2.3	2.0	4	1.7	2.8	2	2.6
5	1.8	14	1.7	1.5	9	1.4	2.2	2	1.9
6	1.4	25	1.3	1.5	14	1.2	1.1	1	1.5
7	1.2	33	1.0	1.1	18	1.0	1.5	4	1.2
8	0.9	22	0.7	0.9	1	0.9	0.9	1	1.0
9	0.4	1	0.6			0.8			1.0
10			0.5			0.8			1.0

The apparent non-fulfillment of theory in the lack of marked increase of bodily motion in the smaller instrument has been discussed in a preceding page.

It would be very desirable to get similar series at sea-level in order to make comparisons with these. In fact such an investigation carried on at each large Observatory would, I fancy, be a revelation to many astronomers.

SPECIAL SCALES.

The primary basis of all special scales is the average range of seeing during the hours of actual or attempted work. To these various observed states of seeing the figures from 2 to 8 are naturally applied, leaving a number or two at each end to meet conditions rarely experienced. So, two results occur; first, as each place has its normal set of conditions it follows that different scales made at the same Observatory, will usually agree upon the figure for the seeing at any time and thus be largely interchangeable, so far as the class of work is at all similar in its requirements. Let me give an example. In our Flagstaff work Dr. See, using his scale on double stars, and I, using mine on Jupiter's satellites, record usually the very same figure; that is because we are both working only near the limits of vision. On leaving work, for instance he has often named the quality of seeing on his scale, and upon turning to the satellites I have exactly confirmed it. But the actual seeing denoted by the same figure, if in the lower part of the scale, is different; for his work is nearly always at

low altitude and mine at high so that when I turn to his region of the sky I record a figure about two points below his for the same region. As the figures become higher in the scale and rarer in occurrence this absolute difference grows less and finally disappears. So our scales although agreeing, usually denote different seeing.

But if some one at the same place were taking meridian transits, or similar observations, his range of available seeing would be much greater; he could work under some conditions that would be prohibitory to us and his scale would be less rigid. So I say that for similar requirements scales at one Observatory will be almost exactly the same in figure, though they may not be at all the same in absolute value.

The second point follows from what has been said above, and is this: that the scale in use at a place, when expressed carefully in terms of the standard scale, becomes an index of the average character of the seeing in that place. This I have never tried but it is a logical conclusion. If, therefore, we can obtain from each Observatory merely the value of their figures of seeing expressed in the standard scale, we shall have a means of comparing directly the character of the atmosphere in different parts of the world and can draw inferences which will be of vast value in the selection of sites for future Observatories.

It is evident that a planet cannot be used in a standard scale because the seeing varies with the apparent size of the disc and of the detail upon it. Such scales however are in constant use because it is difficult to turn the telescope on anything standard like a bright star when one is very busy with planetary work. The proper method is to make a special comparison between the adopted scale after it has become well fixed and constant, and the standard. Some examples of special scales, three planetary and one stellar, in use at our own Observatory, are here given:

SCALE ON MARS, 10″ TO 18″ IN DIAMETER, 24-INCH TELESCOPE.

(By Mr. Lowell.)	(By Mr. Douglass.)
0. Image void of contour or detail.	0. Planet a blur, increased greatly in size, no detail.
1. Limb moving, polar caps and dark areas alone recognizable, latter unstable.	1. Limb very bad, indefinite through 1″, seas visible and possibly whitening at poles.
2. Limb steady, dark areas tolerably so, uncertain glimpses of canals.	2. Limb very bad, indefinite through ½″, first canals visible, as Ganges, Agathadaemon and Chrysorrhoas.
3. Coarser canals as streaks; double canals as very broad ones.	3. Forked bay a little difficult.
4. Coarser canals evident; double canals suspected.	4. Forked bay distinct.
5. Coast lines absolutely sharp.	5. Outline of Sinus Sabaeus fairly dis-

6. Oases visible.	tinct.
7. Finer detail tolerably distinct.	6. Glimpse Phison and Euphrates.
8. Double canals perfectly distinct.	7. Phison and Euphrates distinct.
9. All detail approaches steel engraving.	8. Glimpse Daix.
10. Image absolutely steady throughout.	9. Daix Distinct.
	10. Daix and oases and other canals perfectly distinct.

These scales were gradually developed and afterwards written out independently of each other and as the appearances of a star in the six-inch telescope has only recently been adopted as a standard, direct comparisons between these and a standard are mostly lacking. Yet individual comparisons have been made though not always recorded, and it is believed that these scales conform closely to the standard when the diameter of Mars is over 12″. As the diameter grows less these scales become more rigid, that is, for the same condition of atmosphere, a lower figure applies. For instance when the diameter of Mars is 6″ the seeing will be recorded lower by about two points on this scale of ten. Any one thoroughly acquainted with work on Mars under good atmospheric conditions will perceive that these scales are nearly identical.

The writer's scale on the satellites of Jupiter, observed with a 24-inch telescope, is even more rigid. The satellites are so small that the seeing has to be extremely good in order to do any work on them.

After the scale of seeing became fixed and then had received many direct comparisons with the standard it became evident that it was formed directly from experience in that particular work and depended on the customary qualities of the seeing during periods when the general atmospheric conditions warranted at least a test of the atmosphere; that was by no means a mere question of clouds, for many clear nights passed with only the briefest glimpse through the instrument, experience having shown that under conditions then present work was impossible.

The scale on these satellites, or especially on the third whose diameter is 1″·6, is as follows:

Standard 3 or less.	1.	Greatly enlarged in size, to 3″ or over, no detail.
Standard 4.	2.	Limb very hazy, very rare glimpses of most conspicuous markings by using power 500.
Standard 6.	3.	Diameters possible but of little value, occasional glimpses of detail in power 500 but drawings very unreliable.
Standard 7.	4.	Satellite fairly steady and limb quite distinct; sure of coarse detail in 500 and uncertain glimpses in 750.
Standard 8.	5.	
Standard 8 or 9.	6.	Fine for diameters; detail very distinct in 500 and can be studied to advantage in 750.
Standard 10.	8.	Detail distinct in 750 (these are dark lines estimated to be 1/20 of a second in width).
	10.	(Never seen).

Even with the slight difference in the diameters and brightness of the satellites, there is a difference in this scale. When the third satellite shows the seeing to be between 3 and 5 on its scale, the fourth satellite, which is of the same size but decidedly darker, is usually one point higher on the scale; and the first and second, which are about 1″.0 and 0″.8 respectively, in diameter and a trifle brighter are about one point lower on the scale. In other parts of the scale they all agree.

It is very likely that in fixing this scale the figures in use on Mars were followed. Both for Mars and the satellites 4 is the turning point between profitable and unprofitable seeing; or at least between poor and good seeing, for with persistance seeing below 4 may become profitable.

Dr. See defines the scale for double star work used by himself and Mr. Cogshall in the 24-inch telescope as follows:

0. Light of the star spread all over the field, or expanding and contracting violently.
1. Image greatly agitated, expanding and contracting; perhaps on the average 5″ in diameter (for 6th mag. star,) rays and fringes from 5″ to 10″ long.
2. Image blurred, less motion, but numerous short fringes, no possibility of seeing a close unequal companion, say the 11th magnitude and distance 1″.5, for 6th magnitude star.
3. Image blurred, only slightly agitated but surrounded by short fringes; no sharp definition of the central part, and some faint light still diffused about the image.
4. Image still blurred, scarcely any diffused light or rays, but central disk indistinct.
5. Central disk fairly distinct, no diffused light, only very short fringes, but these moving constantly.
6. Central disk distinct, short fringes in gentle motion; easy to see an equal double separated by 0″.3.
7. Central disk sharp, fringes short and almost motionless; easy to see parallel fringes of an equal double separated by 0″.25.
8. Perfect central image; diffraction rings and fringes seen in gentle motion, will separate an equal double at a distance of 0″.25.
9. Diffraction fringes numerous and almost motionless; easy to see the closest double separable by the telescope (unless very unequal).
10. Diffraction rings and fringes perfect and motionless (never realized for any length of time).

I hope many astronomers will see the wisdom of comparing their special scales in constant use with the standard scale, now for the first time fully discussed, or of determining the mean value of the seeing at different zenith distances in terms of the standard scale or at least of discovering the aperture of a lens which by the form of its stellar image will give the same figure for the seeing as obtained from well-practiced observations of twinkling. And I hope they will speedily publish such comparisons; for everyone will be interested in them because the excellence of any region in the most delicate astronomical work will thus be revealed with absolute impartiality.

LOWELL OBSERVATORY, Flagstaff, Arizona.

April 8th, 1898.

ON THE CAUSES OF THE SUN'S EQUATORIAL ACCELERATION AND THE SUNSPOT PERIOD.

E. J. WILCZYUSKI.

FOR POPULAR ASTRONOMY.

In the beginning of every science isolated facts present themselves which apparently have no connection with each other. As the science is gradually perfected, and relations are found between the different phenomena, the subject becomes more complex and covers a wider stretch than it did at first; but, at the same time, it becomes easier to understand because it is found that all of the phenomena, which have been observed, are but the consequences of certain fundamental laws. In solar physics two laws of fundamental importance have been found, the law of the equatorial acceleration and that of the periodicity of sun-spots. Their great significance lies in this, that they give numerical relations between measurable quantities, and that their consequences can therefore be deduced by mathematical reasoning.

The researches which I have made upon this subject have appeared in my inaugural dissertation. "Hydrodynamische Untersuchungen mit Anwendungen auf die Theorie der Sounenrotation" Berlin 1897, and in some papers in the *Astrophysical Journal.* A brief account has also appeared in the *Astronomical Journal* Vol. XVIII, No. 416. In this paper I will try to present the principal points in popular language.

We assume the Sun to be a fluid body, the general term fluid comprehending both gaseous and incompressible fluids as special cases. Its present condition and the present motion of its parts are then but the consequences of the condition of the nebula from which it has been formed, and of the motion of the parts of this nebula. This is exactly the same as in the case of planetary orbits. The form of the planet's orbit and its position in space was determined by the position and motion of the planet at the time of its formation. Such an orbit must be a conic section, if we neglect the perturbations, and it may possibly be a circle. And just in the same way as a circular orbit is an exception in the case of planetary orbits, only one occurring among an infinite number, so also is it infinitely improbable that a gaseous body starting to rotate should rotate in the same way as a solid mass. It *may* do so, but in general it will not.

But obviously we must take into account the influence of internal fluid friction, which of course tends to make the body rotate

as if it were solid. But the mathematical theory shows this influence to be very small, so small that it will not change the daily arc described by a point upon the Sun by 2′ in 27,500,000 years.

This result is obtained in the course of investigating the following problem. All particles of a viscous fluid describe circles in parallel planes around an axis perpendicular to these planes. The conditions for the motion and figure of such a body are investigated. The angular velocity of rotation is supposed to be different in different parts of the fluid. It is found that an important theorem holds, which we proceed to explain.

The density of the body as well as the temperature may vary from point to point. All points in which the density has the same value constitute, in general, a surface which is called a surface of constant density. Similarly we can speak of surfaces of constant temperature. The theorem which we have in view is this:

In a rotating viscous fluid, the angular velocity of rotation is the same for all points whose distance from the axis of rotation is the same, if the surfaces of constant density and of constant temperature coincide. If we conceive the axis of rotation to be surrounded by a family of coaxial cylinders, the surface of each cylinder rotates as if it were rigid.

This theorem is shown to be very probably true for the case of the Sun, and the surfaces of constant density are calculated approximately. By applying the theorem to the comparison of the different laws of rotation which have been empirically found for the sun-spots, for the faculæ and for the so-called reversing layer, the difference in level of these different solar strata can be ascertained. The discussion of these numbers leads to the result that the solar atmosphere, *i. e.* the region above the "photosphere," is much more extensive than has usually been believed. The contradictions, which seem to rise herefrom at first sight, can be easily cleared up if the power of refraction, which this atmosphere must have, is taken into account. One other important conclusion is that the sun-spots must be higher up in the solar atmosphere than the photosphere, a view which, while opposed to the classical idea of Wilson, is nevertheless constantly gaining more adherents.

If the motion of the solar particles is not strictly uniform and circular, and it is easy to see that in general it will not be so, the deviations from the uniform circular motion cause corresponding changes in temperature, pressure and density, as the equations show. Now it is quite easy to show that these deviations, sup-

posed to be small in comparison with the principal motion, are of an oscillatory character, tending at the same time towards zero. That is, they will be periodic functions of the time but become constantly smaller, in the same way as a pendulum swinging in air oscillates backward and forward, but finally comes to a stop. But in our case this dampening effect is only very slight and may not be noticed for thousands of years. To the periodic variations of the motion will then correspond periodic changes in temperature, etc., and it is extremely plausible that hereto will correspond periodic variations of the Sun's activity. This line of thought gives a very reasonable explanation of the sun-spot period, which is also supported by some numerical work which is meant to show that the causes invoked are sufficient to explain the observed phenomena.

If we remember that the theory sketched out here, is based on no arbitrary assumptions, that it reaches its conclusions by rigid mathematical reasoning, and that it succeeds in uniting the observations of solar physicists, which have been the source of so many wild hypotheses, into one consistent whole, it certainly seems to be a step in the right direction. And it seems to me that we are justified in saying that the rotation-law is the instrument with which to fathom the solar mysteries. It is the fundamental law to which all others, even that of the sun-spot period, are but supplementary.

NAUTICAL ALMANAC OFFICE,
May 6th, 1898,
WASHINGTON, D. C.

WOMEN ASTRONOMERS, (1750-1890.) *

HERMAN S. DAVIS.

FOR POPULAR ASTRONOMY.

A little girl of six years, when taunted one day by her sister with "I am prettier than you," made the ready rejoinder: "But I am the wiser." The future career of Nicole Reine Étable de la Brière, afterwards wife of the famous clock-maker, Jean André Lepaute, proved the truthfulness of her boast. Seven pages of Rebière's book are devoted to an account of her life,—most of it quoted from Lalande's *Histoire abrégée de l' Astronomie.* It is well this has been done for she was Lalande's assistant. With

* Biographical Sketches, and a Review of Rebière's "Les Femmes dans la Science." (Second Paper.)

the possible exception of Clairaut, no one was more competent to speak of her enthusiasm, industry and ability.

Madame LEPAUTE was born at Paris January 5, 1723. In 1748 she was married to the royal clockmaker. This union was advantageous to both in their scientific career. She assisted her husband by observations, by calculations, and by writing descriptions of his handiwork; and in turn she rendered him useful to astronomy.

So great had her repute as an astronomical computer become by 1757 that when Lalande in this year (not 1759 as given by Rebière) engaged Clairaut to apply his solution of the problem-of-three-bodies to the orbit of the comet of 1531-1607-1682 whose return was then being awaited, that able analyst expressed the hopelessness of the task unless Madame Lepaute should consent to assist him. With eagerness she came to his rescue and night and day for eighteen months they toiled together with the one purpose of predicting for the first time in the history of astronomy the date of a perturbed comet's return to perihelion. At last their work came to an end; the results of the calculations were communicated to the Academy of Sciences 14 November, 1758. The comet was seen first by Palitsch 25 December, 1758, and it reached perihelion 13 March, 1759, within the limiting dates fixed by Clairaut and Madame Lepaute. Unfortunately, Grant, in his *History of Physical Astronomy* (page 104), makes no mention of Madame Lepaute's name in this connection; an oversight only too common with that author, who treats history with such fidelity and yet as facts without factors. Nevertheless the one who was best able to judge of her services, Clairaut, appreciated her devotion and industry enough to write, "Her enthusiasm is surprising!" and to call her "la savante calculatrice."

Many other calculations were performed by Madame Lepaute but perhaps her most useful labor for astronomy was, after all, the love for this science which she inspired in her husband's nephew, Joseph Lepaute d'Agelet, who met an unknown fate so early in life in company with the other members of the unfortunate expedition of LaPerouse. As time wore on and no explanation came of the mysterious disappearance of the ship and of all on board, the uncle became sick in both mind and spirit, and Madame Lepaute, worn out with attending him, was taken ill of a malignant fever and died 6 December, 1788.

Lalande stated that Madame Lepaute was the only woman in France who had acquired any true knowledge of astronomy and that Madame Du Piery alone followed her as the distant second.

Madame DU PIERY, whose maiden name was Louise Elisabeth Félicité Pourra de la Madeleine, was born in 1746. She computed most of the eclipses made use of by Lalande in his investigation of the lunar motions; also tables of the lengths of day and night and tables of "refraction in right ascension and declination for the latitude of Paris." Lalande dedicated to her his *Astronomie des Dames*.

* * *

The years 1780-2 are particularly important to those interested in the work of woman for astronomy; for in that period were living Kirch, Le Paute, Du Piery, Lalande, Agnesi, Matt, Herschel, Witte, Somerville, besides many writers on astronomical subjects who were of less importance.

Marie Jeanne Amélie Harlay, who afterwards became by marriage a niece of the first Lalande, was born in 1768 (not 1760 as Rebière says). She made such reductions as were necessary for the 10,000 stars of her husband's catalogue published in 1799; besides much other work of the same kind published at various times by herself. Madame LALANDE's only daughter was born on 20 January, 1790. On this day was seen for the first time at Paris the comet which was discovered by Caroline Herschel. For this reason the infant was named Caroline,—a son had previously been named Isaac in memory of Newton. Madame Lalande took much pains to train A. H. G. Cassini as an astronomer that he might follow the traditions of his four illustrious ancestors and thus be Cassini V in astronomical biography. He did work for a while at the Paris Observatory, but after a few months devoted himself exclusively to botany. Madame Lalande lived until 1832.

MARIA GAETANA AGNESI was the daughter of Pietro di Agnesi, a feudal lord of Monteveglia and professor of mathematics in the University of Bologna. She was born 16 March, 1718.

Jetzler in a letter of 26 March, 1776, to Dr. Hegner says: "We know that everything which Madame du Châtelet and Donna Agnesi have written was not hatched in their own heads." It no doubt is true that Maria's father rendered her instruction and very efficient aid in her prosecution of mathematical and astronomical studies. It is no less true that Maria herself was really a natural prodigy. When only nine years of age "she knew Greek and Latin and had begun a translation of a classic on Mythology." At the age of thirty she published her *Instituzioni Analitiche*—an exposition of the Newtonian doctrines. This work quickly replaced the writings of the Marquise du Châtelet.

Montucla said of it: "It merits a distinguished place among the best books upon analysis. Its readers will not peruse it without astonishment that a person, of a sex so seldom accustomed to familiarity with the rigors of scientific thought, has penetrated so profoundly into all parts of analysis, whether ordinary or transcendental."

In 1750, during the illness of her father, Maria supplied his place as professor in the University. But shortly after his death she retired to the nunnery where she remained until her own death, 9 January, 1799. She renounced entirely her devotion to science when she assumed the robes of a nun. Thus in sequestered religious devotion she sought for that solace of mind and soul which pursuit of earthly glory in the ways of science alone can never attain.

Rebière devotes seven pages to the biography of this wise woman. He reproduces, in addition, her portrait, a three-page facsimile of one of her scientific letters, and a facsimile of the first page of her *Instituzioni.*

As Milan was the city of her birth, so too is it the city which has loved best to honor her memory; and within recent years her statue has been set up in the open court of the Brera in company with those of many a man famous for rare scientific endowments.

Elisabeth von Matt, a baroness of Vienna, built there a small Observatory and equipped it with a Reichenbach transit and several other excellent instruments. Her numerous observations were published in Bode's and Zach's Zeitschriften; at first anonymously and afterwards over her own name. The *Berliner Jahrbuch* previous to 1814 contains many of her contributions to astronomy: and that of 1817 contains her biography by Bode, who speaks of her in very complimentary terms. This intensely practical woman died suddenly in 1814 shortly after setting up a beautiful telescope which had been under construction for seven years.

Wilhelmine Böttcher was born in 1777 at Hanover, Germany. Having married early in life she is more frequently known as Wilhelmine Witte. She owned a fine Fraunhofer telescope and was well practised in its use. From her own observations and with the aid of Maedler's moon-chart she made a spherical model of the moon. This was thirteen inches in diameter and made with such skill and fidelity to every detail of light and shade and configuration as to be the object of great praise by Sir John Herschel and other specialists. At the request of Alexander von Humboldt she made a duplicate of it for Friedrich Wilhelm III.

MINNA WITTE, daughter of Wilhelmine, became the wife of Maedler and assisted him in observing the solar eclipse of 18 July, 1860, as well as in other astronomical work.

On page 191 of his book, Rebière gives to a Mrs. LIND the credit of 'discovering (?) the craters of the moon', 4 May, 1783, while she was using the telescope in company with W. Herschel.

Miss SHORT erected and superintended an Observatory on the Calton Hill, Edinburgh. She was a descendent of a brother of James Short, who lived from 1710 to 1768 and was an instrument maker of considerable repute. Miss Short possessed a Gregorian reflector of about twelve-feet focal length. It was erected in her Observatory with equatorial mounting about 1776.

CAROLINE HERSCHEL, sister of Sir William Herschel, was born at Hanover, Germany, 16 March, 1750, and died at the same place 9 January, 1848, after spending the greater portion of her ninety-eight years in the service of astronomy as her brother's assistant, during their residence in England.

Eight comets (not seven as Rebière says) were discovered by Caroline Herschel. She also published several catalogues of stars and nebulae. It has been said that her memory and ability as a computer on these catalogues were so defective that she always kept with her even a small multiplication table ever ready for use. It was only "by sheer force of will and devoted affection that she learned enough of mathematics and of methods of calculation to enable her to commit to writing the results of her brother's researches. It was he whom she loved and believed in and helped with all heart and with all her strength. She was jealous of every word said in her own praise: jealous, however, lest it be just so much taken away from the honor due to her brother. Such devoted assistance to him could not but be crowned with success for them both."

Very apt in this connection is the remark by Hamerton in his *Intellectual Life:* "The clever woman is the best of pupils when she loves her teacher, but the worst of solitary learners."

Yet even to this statement there are exceptions and the most noted one is MARY SOMERVILLE, née Fairflax. She was born 26 December, 1780, in Roxburghshire, Scotland just on her mother's return from London, whither she had gone to see the husband off to join British forces making war on the American Colonies.*

* It might be added in this connection that Washington's mother belonged to this Fairflax family; and while Lieutenant Fairflax (not Admiral, as Rebière says) was on board a man-of-war in American waters "he received a letter from General Washington claiming him as a relation and inviting him to pay him a visit, saying that he did not think that war should interfere with the courtesies of private life; but party spirit ran so high at that time that Lieut. Fairflax was reprimanded by his superiors for being in correspondence with the enemy."

The earlier years of Mary's life were spent at home; but when sixteen, she went to a near-by boarding school where she was utterly wretched because of the change from perfect freedom to perfect constraint. She there wore "stiff stays with a steel busk in front and shoulder-bands. A steel rod with a semicircle which went under the chin was clasped to the steel busk in the stays." Thus attired (or tired) she was forced to daily "learn by heart" a page from Johnson's *Dictionary*—not only the spelling, but the parts of speech and the meaning and even the consecutive order of the words,—a sort of Delsarte System *à la* Inquisition! It is highly probable that her later skill in painting, in music, in mathematics and in science, were in no degree facilitated by her twelve-month training in this school. Her mastery of algebra and geometry was certainly gained in secret and without any extraneous help.

In 1804 she married her cousin, Samuel Greig. The union was an unhappy one, as he was utterly unable to appreciate her intellectual talents; but after three years and the birth of two children he died. In 1812 she married another cousin, William Somerville, a physician in the royal Navy and the first white man who ever was known to have traveled through South Africa from the Cape of Good Hope as far as to the Orange River. This husband admired his wife's ability and encouraged her intellectual pursuits.

Mary Somerville's principal astronomical writings are: *Mechanism of the Heavens*, published in 1832; and *Connection of the Physical Sciences*, in 1834. The former book won from Laplace the compliment that she was the only woman who understood his works. In the latter book is to be found this sentence:

> "If, after the lapse of years, the tables formed from a combination of numerous observations should be still inadequate to represent the motion of Uranus, the discrepancies may reveal the existence, nay, even the mass and orbit, of a body placed forever beyond the sphere of vision."

James Couch Adams told Mrs. Somerville that it was this sentence which suggested to him the idea of computing the elements of the orbit for the disturbing body which was afterwards discovered and named Neptune.

The success of this woman's life may be attributed to her persistent, even obstinate, determination to conquer every difficulty which arose to thwart her devotion to science. Her enthusiasm is evident in every page of her writings, which are remarkable for their clear and crisp style.

In 1835 she received a pension of $1500 from the Government. She died 29 November, 1872, at Naples whither she had gone for rest.

In the near by city of Rome, in the following year, died CATHERINE SCARPELLINI at the age of sixty-five. She was the niece of Félicien Scarpellini, who founded the Capitoline Observatory, revived the Academei dei Lyncei and taught astronomy at the two Universities of Rome. She herself, under such patronage, was predestined for science; her mental proclivities tended in the same direction.

She organized a meteorological station and edited a monthly Bulletin. On 1 April, 1854, she had the good fortune to discover a comet. To Catherine Scarpellini is due the first catalogue of meteors observed in Italy, and some studies of the probable influence of the Moon upon earthquakes. She was the honorary member of many learned societies; and in 1872 was voted a gold medal by the Italian Government in recognition of the value of her statistical work. To these testimonials of her scientific attainments may be added the statement that she was also a devoted mother. At her death poems were written to extol her virtues and a statue was erected in Campo Verano, in Rome, to perpetuate her memory.

* * *

In less than half a century after the birth of the great American republic, there was born in a little insular town MARIA MITCHEL. She was destined, thus early in the history of the Republic, to claim here for her sex a rank corresponding to that given in Italy by Scarpellini, in Germany by Madame Rümker, in England by Caroline Herschel.

When eighteen years old she was appointed librarian of the Nantucket Athenaeum, which position she held for twenty years. The roof of the building was her Observatory; and from there she discovered a comet on 1 October, 1847. In honor of this the king of Denmark presented her with a gold medal. In 1865 she accepted the professorship of astronomy at Vassar College. This position she held until the enfeeblement of age necessitated her resignation. On 28 June, 1889, she died.

Maria Mitchel has summarized her own character in the words: "I was not born with much genius, but with great persistency."

A few women have had their names enrolled by Rebière merely because they are women of some historical importance, and have acquired some repute for having simply studied astronomy with a greater or lesser degree of thoroughness.

Such are:

Catherine de Medici, Italy, 1519-1589
Tarquina Molsa Italy, -1670-
Louise de Saxe-Gotha, a duchess who observed and calculated "with marvelous success" under the patronage of Baron von Zach, -1786-
Pauline Daru=Marquise d'Oraison, France, -1890
Adelaide Louise de Blocqueville, France, -1892
Countess N. Bobinski, whose determination of the definitive orbit of Comet VI, 1891, based on about one hundred observations was presented to the Academy of Sciences of St. Petersburg, 27 November, 1893.

Other women have been classed in the rank of astronomers by Rebière more particularly because their literary or linguistic attainments have been directed towards the production of popular writings on this subject or towards the translation of such writings from another language. Among these may be mentioned:

Marie Coste-Blanche, France, -1570-
Theodora Danti, Italy, -1580-
a relation of Ignatius Danti, who assisted in the Gregorian reform of the calendar
Alphara Behn, England, 1640-1689
whom Gibbon called the "incomparable Behn."
Sophie Granchamp, France, -1750-
the intimate friend of Madame Roland.
Marie Anne du Bocage, France, 1710-1802
praised by Clairaut and Voltaire.
Mrs. Margaret Bryan, England, -1800-
a teacher as well as writer.
F. B. Burton, England, -1837-
Hortense Allart de Méritens, France, 1801-1879
an historian of some merit and friend of Chateaubriand in his old age.
Tiphaine Raguenel = Dugueselin, France,
who won Dugueselin as a husband by the success of her astrological predictions regarding him.
Hannah M. Bouvier, America, 1811-
Sophie Ulliac-Trémadeur France, -1844-
Ginot-Desrois, France, -1847-
inventor of a perpetual calendar.
V. de Beaufort, France, -1852-
Caterina Bon-Brenzoni, Italy, -1853-
poetess and great admirer of Mary Somerville to whom she dedicated some of her poems.
Mrs. Room, -1865-

Vinot,		-1869-
who was her father's assistant as well as an authoress.		
E. S. Lyle,	England,	-1870-
Mary Ashley,	England,	-1880-
whose specialty is selenography.		
Agnes Giberne,	England,	-1880-
Pogson,	India,	
Mrs. J. Norman Lockyer,	England,	
Ellen M. Clerke,	England,	
sister of Agnes Mary Clerke.		
Mrs. Mabel Loomis Todd,	America,	
Mary Proctor,	America,	
daughter of Sir R. A. Proctor, the astronomer.		

But when judged by any sound criterion it must be admitted that AGNES MARY CLERKE is the one woman who has the necessary qualifications to make her writings of more than ephemeral interest. A careful sifting of facts, due assimilation of them, with a happy diction that is at the same time both popular and scientific, place her in the foremost rank of writers on astronomy.

Miss Clerke was born in the county of Cork, Ireland. Having the run of her father's library, she imbibed, while still a child, a love of science, and more especially of astronomy. Her education in music and modern languages was conducted at home, and she taught herself elementary mathematics.

From 1870 to 1877 she resided with her family in Italy. In the latter year she sent an article on *Copernicus in Italy* to the *Edinburgh Review*. Its acceptance decided her literary vocation, and she has ever since continued to be a regular contributor to that Journal. Her first separate publication, *A Popular History of Astronomy during the Nineteenth Century*, appeared in 1885, and a third edition in 1893. A translation into German, by Hermann Maser, was issued at Berlin in 1889.

In 1888, Miss Clerke spent two months at the Royal Observatory, Cape of Good Hope, observing the southern heavens, and published in 1890 *The System of the Stars*, in which she embodied some of her new experiences.

For these two works she was awarded, in 1893, the Actonian Prize of one hundred guineas.

A voyage in the yacht "Palatine" to the fiords of Norway, to Copenhagen, Stockholm, and St. Petersburg occupied the summer of 1890. Turning for recreation to the study of Greek, she published in 1892 a volume, addressed to the general reader, entitled *Familiar Studies in Homer. The Herschels and Modern*

Astronomy, in the "Century Science Series," followed in 1895; and two sections of *Concise Astronomy* in Hutchinson's "Concise Knowledge Library," in 1898.

Miss Clerke has contributed about one hundred lives of men of science to the "Dictionary of National (England) Biography:" and in the ninth edition of the "Encyclopædia Britannica" the articles on Galileo, Kepler, Lagrange, Laplace, Lavoisier, Olbers, Pond, Zodiac, etc., are from her pen. It is with great frequency that the initials A. M. C. may be seen attached to essays and notices in Nature, Knowledge, The Observatory, Saturday Review, Youth's Companion, etc., etc.

March, 1898,

COLUMBIA UNIVERSITY, New York City.

WOMEN ASTRONOMERS,* (*Contemporary.*)

HERMAN S. DAVIS.

Only five pages from the end of the sixth volume of his vast work, *Histoire de l'Astronomie*, Delambre puts aside his customary style of severe criticism and pleasantly quotes from the "Literary Correspondence" of La Harpe an anecdote regarding Messier:

"Louis XV called him the 'comet-ferret.' In fact his whole life was devoted to the search for comets; moreover he was a very honest man, of childlike simplicity. Some years ago he lost his wife, and while rendering her the last sad rites he failed to be the first to see a comet for which he had been watching. Montaigne de Limoges anticipated him and thus he was in despair. When someone endeavored to comfort him for the family loss he had sustained, thinking only of the comet, Messier replied: 'Alas, I had discovered twelve and Montaigne had to rob me of the thirteenth!' Then the tears came into his eyes, but suddenly remembering that it was for his wife he ought to weep, he sobbed out: 'Ah, my poor wife!' and went on mourning—*for the comet!*"

All astronomers have not been so unmindful of their wives,—at least not while they lived. It is impossible to estimate how many results both great and small have been due to the encouragement rendered to astronomers by their wives; their struggles together against poverty, and in quest of ambition's *ignis fatuus*. But where such assistance has become a matter of record or common report, it is a cheerful duty to perpetuate the remembrance of it.

It has been already narrated how greatly Hevelius prized his wife's coöperation in observing for the catalogue of fixed stars.

* Biographical sketches and a Review of Rebière's "Les Femmes dans la Science." (Third paper).

Similar praise is due to Mrs. MARY ANNA FALLOWS, nèe Hervey; for after various vicissitudes arising from removal or death of several assistants at the newly founded Royal Observatory of the Cape of Good Hope, Fallows (while even himself ill) was finally left with Mrs. Fallows alone to help him. This she did with such eminent satisfaction that in his report to the Council of the Astronomical Society, Fallows states that he had "the pleasure of finding his *most efficient* assistant in the partaker of his affections."

Madame RUMKER assisted her husband, computed comet-orbits and herself discovered a comet 11 October, 1847.

Yvon-Villarceau states in the preface of one of his memoirs:

"The formulas upon which rests my method (for the calculation of orbits of binary stars) have been the object of several numerical applications which were executed by Madame YVON-VILLARCEAU, after she had herself verified their analytical exactness.

"Most of our confrères of France and abroad have appreciated the devotion to general interests and to those of science in particular of which she has never ceased to give proofs. These will understand the sentiment which dictates the preface placed at the beginning of this memoir. It is useful to lengthen the list—as yet short enough—of women who, by their active and devoted collaboration, have contributed to the progress of science. To the names of Madame Le Paute, of Caroline Herschel, and of Miss Mitchel, astronomers will add that of Madame *Yvon-Villarceau.*"

Nor will astronomers add her name alone, but also that of Lady HUGGINS, whose studies in spectroscopy in collaboration with her eminent husband, as well as her separate writings, have given her a high and worthy place among contemporary investigators.

Madame FLAMMARION is accredited by Rebière with a taste for astronomy and with the authorship of several articles bearing upon this subject. Rebière also quotes the *Annales de l'Observatoire du Puy-de-Dôme* as issued in 1896 by M. *et Madame* J. VALLOT.

At the Observatory of Natal, South Africa, Mrs. NEVILL is the senior assistant to her husband, the Director, E. Neville Nevill.

It would be an ungrateful assumption of modesty for the writer not to mention in this connection the continuous labors of his own wife, Mrs. Coreita R. DAVIS—at present, in work upon the new reduction of Piazzi's catalogue of 7646 stars; and in the past, in no small portion of the computations connected with the following publications:

Mean Epochs of Observations of the DLX Stars of the Abo Catalogue of Argelander.

Parallax of Eta Cassiopeiae, deduced from the Rutherfurd Photographic Measures.

Catalogue of Sixty-two Stars about Eta Cassiopeiae.

Declinations and Proper Motions of Fifty-six Stars for the Variation of Latitude Investigation at New York and Naples.

Catalogue of Sixty-five Stars near 61 Cygni.

The Parallaxes of 61^1 and 61^2 Cygni, deduced from the Rutherfurd Photographic Measures.
Catalogue of Thirty-four Stars near 'Bradley 3077.'
On the Permanence of the Rutherfurd Photographic Plates.

Some other women, most of whose names are given by Rebière because they have taken part in astronomical computations or are teachers of astronomy, are:

HELLEN HAYES, who is instructor of mathematics at Wellesley College, and who published the orbit of one of the minor planets.

CHARLOTTE R. WILLARD, formerly assistant at the Goodsell Observatory, Northfield, Minn., and for several years associate editor of "POPULAR ASTRONOMY."

MARY WATSON WHITNEY who is Maria Mitchel's successor as Director of the Observatory of Vassar College.

CAROLINE FURNESS, assistant at Vassar College.

F. G. WENTWORTH, who has contributed several papers to the various astronomical publications.

MARY EMMA BYRD, Director of the Observatory of Smith College, Northampton, Mass.

SUSAN J. CUNNINGHAM, Director of the Observatory of Swarthmore College, Penn., and who is at present engaged, in collaboration with FLORA E. HARPHAM, upon a determination, from all available catalogues, of the proper motions of the 7646 stars contained in Piazzi's *Stellarum Positiones Mediae*.

ROSE O'HALLORAN, of San Francisco, Cal., whose numerous observations of eclipses, meteors, variable stars, etc., frequently appear in "POPULAR ASTRONOMY" and other periodicals.

HANNAH MACE, formerly assistant at the U. S. Naval Observatory.

Mrs. ELIZABETH P. B. DAVIS, who for a number of years calculated the Ephemeris of the Sun for the *Nautical Almanac*; besides miscellaneous work on comet-orbits and proof-reading of text-books on mathematics. Mrs. MARY EDWARDS did a very similar class of work in the office of the British *Nautical Almanac*, at the close of the last century.

Miss WALKER is an assistant in the University Observatory, Cambridge, England. "She has rendered valuable assistance" in the computation and arrangement of the catalogue of 14,464 stars recently issued by Graham as Part IX of the Astronomische Gesellschaft zones.

MARGUERITE PALMER has published several memoirs in the *Transactions* of the Yale Observatory, and has computed a definitive orbit for the comet discovered by Maria Mitchel.

ALICE LAMB, now Mrs. Milton Updegraff, was assistant as-

tronomer in the Washburn Observatory from June, 1885, to September, 1887. She had charge of the extensive time-service of the Observatory and also took part in the regular series of observations with the Repsold meridian circle. She also made many observations of the minor planets and double stars with the 15.5 inch equatorial telescope. At this time she also prepared and published in Vol. V of the Washburn *Publications* an Index to the six Greenwich catalogues according to a plan suggested by Argelander. Volumes IV, V, and VI of the Washburn *Transactions* contain many of her observations and other work.

In September, 1887, she was married to Professor Updegraff and went with him to the Argentine Republic where they both served as astronomers in the National Observatory from November, 1887, to March, 1890. She had charge of the time-service there and also participated in the observations of Dr. Auwers' list of 480 southern stars, and in the reductions of the same. Since returning to the United States she has retained her interest in astronomy, and is now preparing for publication a translation of Ruhlmann's *Barometrische Hohemessungen*.

Connected with the British Astronomical Association are several women. Miss ELISA BROWN was sent to Kineshma, near Moscow, to observe the total solar eclipse of 19 August, 1887. She is the director of the solarsection of the Association.

Miss A. S. D. RUSSELL was from September, 1891, to November. 1895, on the staff of computers of the Greenwich Observatory, She was also editor of the *Journal* of the British Astronomical Association. On 28 December, 1895, she was married to Mr. E. W. Maunder, the astronomer.

ALICE EVERETT, after taking the degree of A. M. with honors at the University of Cambridge, England, became an assistant in the astro-photographic department of the Greenwich Observatory and for two years acted as secretary of the Association. She is now an assistant at Potsdam.

* * *

The application of photography to astronomy, whereby the determination of star-positions, spectra-type, variability, etc., become laboratory rather than Observatory work, has wonderfully increased the opportunities for woman in pursuit of the truths of nature.

Twenty-five years ago Miss IDA C. MARTIN was Rutherfurd's assistant in the measurement of the plates made by him at that period. All the earlier *Contributions* issued from the Observa-

tory of Columbia University, New York, based on the Rutherfurd plates, depend entirely on her measurements.

But the most extended application of the aid of women in this specialty has been under the directorship of Professor Edward Pickering at Harvard Observatory, where a large force of women is constantly employed under the supervision of Mrs. Fleming.

Mrs. Williamina (Mina, MARGARET) PATON FLEMING, née Stevens, was born in Dundee, Scotland, 15 May, 1857. In 1877 she was married to James Orr Fleming also of Dundee. In 1879 she came to the United States and secured employment at Harvard Observatory as a computer. Since then the responsibilities of her position have increased until now she is in charge of the department for examination of the thousands of photographic plates taken with the Draper telescope. In the course of this examination, Mrs. Fleming has discovered a large number of variable stars and confirmed the discovery of several new stars.

Mrs. Fleming is ably seconded in this work by Miss E. F. LELAND, A. C. MAURY, M. C. STEVENS and L. D. WELLS, all of whom are women having more than one discovery to their individual credit.

Of all those who are now engaged in this kind of photographic research, she who seems by study and natural ability to be best qualified for attacking the manifold problems that present themselves is Miss DOROTHEA KLUMPKE. She was bor.. in San Francisco, but left there in her youth and spent several years in Germany, Switzerland and Paris. In 1887 she was a student at the Observatory of Paris and acted as translator for the first Astrophotographic Congress, which convened that year.

Her observations of several minor planets (Millosewich, Charlois, Borelli, Wolf, etc.) and of the Temple-Swift comet have been published in the *Comptes rendus de l'Academie.*

On 23 December, 1893, Miss Klumpke sustained her doctorate thesis before Darboux, Tisserand and Andoyer. It was a purely theoretical study of the rings of Saturn. At the conclusion of the examination Darboux remarked: "Your thesis is the first which a woman has presented and successfully maintained, with our Faculty, to obtain the degree of doctor of mathematical sciences. You worthily open the way and the faculty votes unanimously to declare you worthy of obtaining the degree of 'Doctor.'"

Dr. Klumpke is now at the head of the bureau for the measurement of the plates of the astro-photographic catalogue at the

Paris Observatory. She is assisted by the Misses SCHOTT, MARQUETTE, CONIEL, DAUPHIN and LAMPDON.

* * *

Notwithstanding the manifold variety of ways in which the preceding sketches reveal woman's application of thought and energy with such success to the cultivation of astronomy, there is, perhaps, no way in which woman has contributed more effectively towards the progress of this science than by the use of her donative faculties. The patronesses of astronomy have been and still are both numerous and munificent.

One of the earliest of these was the Countess ELISABETH D'OGINSKY PUZYNINA, who founded one of the Observatories of Poland.

ANNE SHEEPSHANKS (1789-1876) was the founder of an astronomical scholarship at Trinity College. This scholarship was to be paid out of a donation of $50,000 devised as a contribution to the advancement of astronomical science in the University of Cambridge. In 1860 she contributed the additional sum of $10,000 for the purchase of a new transit circle for the Cambridge Observatory. This was mounted in 1870 and thus rendered it possible for Graham to take part in the zone observations of the Astronomische Gesellschaft. The resulting catalogue of 14,464 stars was published in 1897.

Madame GUZMAN who died at Pau, France, June, 1891, at the age of ninety-two left provision in her will for a "prize of $20,000 for the person who will find a means of communicating with a star (Mars for example) and receive a reply from it."

The Baroness DAMOISEAU founded in honor of her husband an astronomical prize to be bestowed each year by the Academy of Sciences of Paris.

Madame VALZ, in 1874, left to the Academy of Sciences of Paris the sum of $2,000 for the founding of a prize likewise to be bestowed for work in astronomy.

The report of the Observatory of Paris for 1895 states that Miss BRUNNER presented to the Observatory several instruments which had belonged to her father.

Madame d' ABBADIE and her husband left their entire fortune to the Academy of Sciences of Paris on condition that there should be completed within fifty years a catalogue of 500,000 stars.

Among American patronesses we would mention:

BLANDINA DUDLEY contributed over $27,000 towards the found-

ing of the Dudley Observatory at Albany which in consequence is named in honor of herself and husband.

Miss BERENICE MORRISON is the woman whose liberality made possible the founding of the Morrison Observatory at Columbia, Missouri.

Mrs. WILLIAM THAW, in continuation of the generosity of her husband, has contributed very largely towards the finances of the Allegheny Observatory where the labors of Langley and Keeler have done so much to add to knowledge of the heavenly bodies.

Mrs. HENRY DRAPER of New York City has presented to Harvard Observatory some of the instruments used by her husband in his valuable and early researches in astronomical photography and spectroscopy. She has also contributed generous sums of money in memory of her husband to aid in the prosecution of similar studies at Harvard.

The most recent patron for the toil of the astronomer is Miss ALICE BACHE GOULD who has presented to the American National Academy of Sciences the sum of $20,000. The income of this is to be devoted to aiding such researches in the astronomy of precision as shall be judged worthy of it by a committee at present composed of Professors Chandler, Boss and Hall, editors of the *Astronomical Journal* founded by the renowned father of the donor.

The most unbounded liberality so universally bestowed by Miss CATHERINE BRUCE upon every branch of astronomy in all parts of the world will make her name go down to future ages as worthy of unstinted admiration. One can hardly pick up an astronomical publication in these days without finding a mention of some new gift from her to astronomy. $250 to purchase a small instrument for some zealous astronomer in a far-away island of the sea; $25,000 to aid in the removal of a vast Observatory to a better location; $1,500 to pay for printing valuable astronomical researches; $50,000 to purchase a new photographic telescope; are but a small portion of her benefactions, bestowed with such wisdom as to make the first gift no less acceptable than the last. Miss Bruce has been called the "Maecenas of Astronomy," a compliment which might well be bestowed upon her if it were not that she is creating even a greater name for herself.

* * *

One naturally asks himself the questions:

(1.) What is the proper place for woman, hitherto, in the history of astronomy by reason of results actually attained?

(2.) In what respect is it advantageous or disadvantageous to herself and to the Science for women to adopt astronomy as a profession?

(3.) What are the coming possibilities of, and limitations to, her career in this noblest of the sciences?

(4.) From a utilitarian point of view, does her success repay the expenditure of energy of mind and of body incident to laborious computations: and repay the abnegation of her customary pleasures of life? Or, from the æsthetic aspect, is the work sufficiently its own reward: and does the evidence indicate that the study of starry wonders is satisfying to the ambition and to the spirit?

While reading the foregoing sketches of the life and work of many women astronomers doubtless the reader has already conceived answers to these questions which it would be rude for the writer to oppose or needless to support by his own opinions. Suffice it to say that in these three papers, suffering, devotion, patience, persistency, generosity have been the constant record, to which has been added in some instances a deep intellectuality.

And whatever woman may be capable of, individual cases, at least, show that she can do much and do it remarkably well when her enthusiasm is thoroughly aroused: that her patience is limitless, her devotion unbounded; but that, above all, her sympathy for those nearest to her, her appreciation of their toil, her encouraging words and actions that speak louder than words, inciting them to renewed exertions when discouraged by repeated failures until at last all the toil is rewarded by success—these have accomplished as much as all else that woman has done towards showing

> . . . . . à de certains esprits
> Dont l'orgueilleux savior nous [les femmes] traite avec mépris,
> Que de science aussi les femmes sont meublées . . . .

* * * * *

A few errors in *Les Femmes dans la Science* may be noted here:

Marie Kirch was born in 1670 not 1660, (page 153) and several other dates have in a similar manner been corrected in the text of these three papers for POPULAR ASTRONOMY.

Mrs. Fleming can hardly be characterized with propriety as an *historian*, nor should her name be spelled 'Flemming.' (Pages 106-7)

This matter of orthography, however, seems to rest lightly upon the author's conscience, if one may judge by the frequency of errors and the multiplicity of ways in which the same word is rendered in different parts of the book. I shall point out only a few: the numbers indicate the page.

Whithney, 208: Withney, 214: Whitney, 282, are three presentations of the same good name; and Wassar, 143: and Vassar, 282 do indiscriminately as the name of one of our famous colleges for women, as do Wellesley, 44, and Welleslay, 132, for another; or Mount Hyloke, 43 and Mt. Holyoke, 251, for a third.

A twist of the letters may be sometimes due to the oversight of the proof-

reader: Wordl's for World's, 269: Chataugnan, 214, or Chautaugnan, 326, for Chautauquan:

We notice also instances of Harward College, 43, 282: but Harvard, 44, 180: Waschburn for Washburn, 173: Sprinfield, 174: Manova for Manora, 196: Folligno, for Foligno, 250: Pensylvanie, 252: litterature, 42: Wat for what, 194: Piazzi-Smith for Piazzi Smyth, 227: Boodwitch for Bowditch, 40.

But perhaps the only really serious blunder in the entire book is the division of praise for Miss Catherine W. Bruce's generosity into two parts; whence it is made to appear on page 43 that Miss C. V. Broca (!) has contributed $50,000 for the construction of a photographic telescope for Harvard College; and on page 44, the American, Miss C. W. Bruce in equally bold-faced type is stated to have made an exactly similar contribution for the same purpose. To be sure, double praise is due Miss Bruce for her unstinted generosity, but she has no need of a double name and two biographical sketches.

There have been some scarcely justifiable omissions by Rebière. Where these could be readily supplied from the writer's notes they have been inserted in the course of these three papers. Nor have the biographical notices been a translation merely of Rebière; but whatever has been written additional to the matter given in his book has been done with the view of supplementing his, not of completing it.

The form adopted by Rebière for his publication was in some respects infelicitous. Though the book is an alphabetically arranged dictionary, there are no cross-references where the same person was known by more than one name, which is especially common in the lives of women. Nor are the names always in the proper order: Piazzi Smyth is classed with P instead of S, etc.

References and titles of books are several times mis-quoted, viz:

page 196, Maedler I, 390 should be II, 422.

page 151, the title of Gibbon has suffered serious ellipsis.

Notwithstanding the small (?) space of country over which it would seem one must look to find the location of Newnham College, U. S. A., I have been as yet unable to find it by aid of Government educational reports, etc. As this is a matter of geographical knowledge, I may add also that (barring the presumption of an American criticizing a Frenchman in the use of his native language) either the author's French or his geography is at fault in the use of à instead of *en* before *Missouri* on page 141.

In spite of the frequency of trivial errors, of which the above are illustrations, the very excellence of the book as a whole, however, is the main justification for some mention of them here, that the next edition, which presumably must appear in a few years, may be free of these and all similar errors.

(THE END.)

March, 1898,

COLUMBIA UNIVERSITY, New York City.

COMETS AND COMET FAMILIES. IV.

W. W. PAYNE.

In this study of comets, the idea of the families belonging to the planets has occupied our attention quite fully in the three preceding papers. We have noticed important features of the members of particular families, not for the purpose of learning family traits, (for none exist in regard to appearance, or likeness of constitution), but only because the comets were interesting as individual celestial bodies. The main point of family relation to which at-

tention has been called, is the aphelion of the comet orbits as related to the path of the planet whose name the comet family bears. That these points, in any particular family, should cluster, in or near, one part of the planet's path is a natural consequence of the drift of the solar system in space.

The next inquiry is concerning the existence of a comet family for some planet beyond Neptune. To some it may seem singular that any attempt would be made to name or locate a comet family for a trans-Neptunian planet when no such planet is now known. From our study of the families of comets so far, it would not be very easy to find a planet from the aphelia of a company of comets, the periodic times of which are roughly about one-half that of the planet.

If an attempt of this kind were made by any one, astronomers would think that such efforts would be many times less likely to prove successful than the methods that have been commonly used in searching for new and distant planets since the discovery of the planet Neptune. Our readers generally know, we suppose, that the existence of a trans-Neptunian planet has been supposed to account for the irregular motions of Neptune in the same way that the existence of the planet Neptune was presupposed and its place computed which soon after led to its discovery. This way of discovery was tried by Professor Todd of Amherst College Observatory in 1877. He employed the outstanding differences between the observed and the computed places of Uranus (after allowing for Neptune's attraction) and so concluded that those unexplained differences could be accounted for by the attraction of a new planet. He made careful search over an area about 40° long and 2° wide, with the Washington 26-inch telescope, in the hope of recognizing a new planet, but was unsuccessful in the attempt.

Although such methods are undoubtedly the best now known, for the purpose of finding the new planet if such an one exists, it should not be thought unwise to give attention to any and all reasonable means of research for the same object, even if, at the outset, the way of study seem less promising. As long ago as 1884, Camille Flammarion* hinted at the probability, that a fifth group of comets existed which might constitute a planet family for an unknown member of our solar system whose distance from the Sun may be about twice that of the planet Neptune, with a probable period of revolution of about 300 years. The distance, then, of the aphelion of the supposed planet would

* See L'Astronomie Vol. III p. 89, March, 1884.

be 47 or 48 times that of the mean distance of the Earth from the Sun. It is well known that the aphelion distance of Comet III 1862 is 49 units of the Earth's distance from the Sun, and that a comet of 1661 is 48 of the same units. These two comets, on this account, have been suggested, as the members of the family of the unknown planet. As far as known the conditions are similar to those of group 2 and group 3, the families belonging respectively to Saturn and to Uranus. Comet III 1862, which is known as Tuttle's comet is in one regard intensely interesting, and that is, the fact that the comet moves in the same path as that followed by the August meteor stream. This stream is crossed by the Earth every year about the first day of August, and, as its path crosses that of the Earth at an angle, the breadth of the stream is increased, and the display of meteors is likely to last for several nights in succession. Because the angle between the path of the Earth and that of the meteors is considerable the velocity of the meteors is only medium, and the color of their trains yellowish. In these particulars, this stream which has its radiant in the constellation of Perseus, and so are called the Perseid stream, is different from other well-known meteor streams.

The relation of the Perseid meteors to Comet III 1862, was discovered by Schiaparelli of Milan in 1866. Great interest had been awakened at this time by the researches of Professor Newton of Yale University and Professor Adams of Cambridge, England, in regard to the orbit of the November meteors, known as the Leonid stream. After the display of 1866, Leverrier, of France, computed an orbit of this stream, which substantially agreed with that of Adams. About the same time, Oppolzer had computed the orbit of Tempel's comet of 1866 which was nearly identical with that of the Leonid stream of meteors. It will now be readily understood why great interest was felt among astronomers everywhere, in view of these two important discoveries, in quick succession, because they related closely two kinds of celestial bodies which before had been esteemed essentially and remotely different.

It is also an interesting fact that this Perseid stream extends itself nearly or quite throughout the entire length of its great orbit, so we can not speak of the Tempel comet as being in the lead of the stream, or at any other point, to define its position, as is the case in the Leonids and the Andromedes. In each of these streams the comets in their respective paths lead the meteor streams, and the streams themselves are comparatively short and more or less densely packed, but as to swarm, they move with

the same velocity as the comets do. Astronomers say that the Perseid stream is old, because it is so scattered throughout its path. The reason given is the fact that the separate members must scatter from tide-producing effects in an associated mass like a comet. If a comet were a solid mass of large volume it would certainly be broken into fragments by the unequal attraction of the Sun on different parts of so great a mass. This would also be true if the comet were a fluid body, it would be scattered. If we reason from anology, the proofs that show the character of Saturn's rings would equally well apply in regard to comets moving in a path around the Sun.

It would be profitable, if data were at hand, to consider the possible sources of this great Perseid stream of meteors. Did it have its origin in one great comet? Or is it probable that a group of comets were moving in the same path and that disintegration, of the different members of the group have been going on, in different parts of this great orbit, and so, possibly, the period has not been so long, as would be required in the case of a single great comet? Our data are not sufficient to help in deciding such questions. This naturally leads us to the study of the constitution of comets. How much do we know of their real nature? The characteristics of some of the great comets have been mentioned previously and much more could have been said in the same line. Yet, have we any definite knowledge of what these bodies are? If so what are they? We will say something about this next time.

THE LICK OBSERVATORY ECLIPSE EXPEDITION.*

"The story of the eclipse is too long to tell in a letter. I had to locate in *level country*, in a *famine district*, *water scarce*, *dust plentiful*, the plague on both sides of us. There were no habitable buildings nearer than fifteen miles, so camping was a matter of necessity. The difficulties were great, but I kept my courage up, and was all ready for the eclipse on January 16th. The assistants—fine ones—arrived from January 17th to 20th, and were drilled to the work. There had not been a cloud in the sky for six weeks, and exclipse day was simply beautiful. The 'seeing' was fair that day, though it had been poor—Sun boiling—on all previous days.

* Extracts from a letter by Professor W. W. Campbell in No. 61, Publications of the Astronomical Society of the Pacific.

"The eclipse began within half a second of my predicted chronometer time, and closed in the same manner. No wind existed, though I was prepared for wind. The corona had great extent but was faint as a whole. The prominences were numerous, but vastly smaller than in 1893. The sky was *very, very* bright. Animals paid very little attention to the eclipse. Three miles away, on the horizon formed by a low ridge, I saw the small trees with perfect distinctness during totality.

"The 40-foot telescope gave—

1 instantaneous Seed 27 plates.
2 one-second " " "
2 two-second " " "
2 four-second " " "
2 eight-second " " "
1 sixteen-second " " " (defective plate).
1 instantaneous Carbutt B plate (very little on plate).
1 one-second " " (very little on plate, and was caught by the Sun).

"There were eight beautiful negatives with the Dallmeyer and with the Floyd. The spectrum of the Sun's edge was fainter than I expected, but the plates are pretty successful and valuable.

"But I'll save the rest of the story till I get home. I had a great struggle with the dust and the heat in developing the plates. I had to have the dark-room in a tent, temperature 94° Fahr. in the daytime. Had to wait till 1 a. m. to begin developing. And the dust was awful, too. The water was absolutely muddy—had to be boiled and filtered. I never saw such dry climate. Some days the dry bulb was +32° C., and the wet bulb +18° C., or even +17° C. My hands were cracked wide open, and I could scarcely finish the development of the original plates, to say nothing of making copies."

THE ASTRONOMY OF SHAKESPEARE.

ORRIN E. HARMON.

For Popular Astronomy.

What did Shakespeare know of astronomy? This is an interesting question in view of the fact that his vast knowledge of men and things is a growing wonder.

The above question could not properly be asked concerning his knowledge of any of the natural sciences except astronomy.

In his time little was known about physics and chemistry; and geology and the various departments of natural history were yet unborn into the kingdom of sciences.

Hence if Shakespeare knew anything about any of the sciences, it would certainly be about astronomy, the oldest and best developed of them all.

Naturally, we should expect Shakespeare to know much about astrology.

The superstitions about the heavens were common belief in Shakespeare's day; and he put into his writings the thought of the time, moulding this thought with the skill of a seer and a prophet.

While I shall touch briefly upon the astrology of Shakespeare, my main purpose is to find the extent of his knowledge about the real science of astronomy. Happily the greatest name in our literature is easily associated with the oldest and grandest of the sciences.

Our investigation will be materially aided if we will note the time when Shakespeare lived. Copernicus had been dead twenty-one years when Shakespeare was born. Galileo was born in 1564, the same year with Shakespeare; and Kepler was born in 1571, seven years later. Hence, Shakespeare was contemporary with Galileo and Kepler.

The Copernican theory, as we well know, was slowly received even among those who pretended to have a knowledge of astronomy. Galileo, the stout apostle of the doctrines of Copernicus, met only opposition and persecution for defending them; and the third of Kepler's great planetary laws was established about the time of Shakespeare's death which occurred in 1616.

Therefore it would not be strange if Shakespeare's knowledge of astronomy belonged to the old system of Ptolemy, rather than to the new system of Copernicus; and such we find to be the case.

But we shall also learn that, while touching upon all the main points of the old astronomy, he went further, and uttered, as with the voice of a prophet, some of the discoveries of the new.

First let us notice how Shakespeare regarded the science of astronomy. It might be supposed that astronomers did not hold a very high place in his favor if we were to judge his feelings from the following lines:

> "These earthly godfathers of heaven's lights
> That give a name to every fixed star,
> Have no more profit of their shining nights
> Than those that walk and wot not what they are."
> Love's Labor's Lost. Act. I. Sc. I.

This seeming disfavor does not prevent his making frequent mention of astronomy and astronomers. Much in their favor are the following allusions:

"Not from the stars do I my judgment pluck;
And yet methinks I have astronomy,
But not to tell of good or evil luck,
Of plagues, of deaths, or seasons' quality."
Sonnet XIV.

"He will spend his mouth, and promise like Brabbler the hound; but when he performs, astronomers foretell it." Trolius and Cressida, Act V. Sc. I.

Imogen finds no better way of expressing her confidence in the faith and love of Leonatus than by astronomical reference:

"O, learn'd indeed were that astronomer
That knew the stars as I his characters;
He'ld lay the future open."
Cymbelline, Act III. Sc. II.

It will be seen that the common belief of Shakespeare's time was, that the chief office of an astronomer is to foretell the future; and truthfully as Shakespeare spoke of the main features of astronomy, his utterances frequently contain a mixture of astronomy and astrology.

It will now be proper to show Shakespeare's general knowledge of astronomy.

His observations of the heavens are accurate, and in stating these observations he uses astronomical terms with much precision. For instance, the term *zodiac* is used in connection with the measurement of time, and his allusion to the twelve signs shows that he knew the Sun makes his journey through the twelve signs once a year. Notice the following references:

"But this new governor
Awakes me all the enrolled penalties
Which have, like unscour'd armour, hung by the wall
So long that nineteen *Zodiacs* have gone round
And none of them been worn."
Measure for Measure, Act. I. Sc. III.

The "nineteen zodiacs" here mentioned mean nineteen years as will be learned by reading the next scene in the same act.

"Go with speed
To some forlorn and naked hermitage
Remote from all the pleasures of the world;
There stay until the *twelve celestial signs*
Have brought about the annual reckoning."
Love's Labor's Lost, Act. V. Sc. II.

Shakespeare notices not only the year as measured by the Sun's course through the zodiac, but the changing points of his place of rising. Casca says:

"Here as I point my sword, the Sun arises,
Which is a great way growing on the south,
Weighing the youthful season of the year.
Some two months hence up higher toward the north
He first presents his fire; and the high east
Stands, as the Capitol, directly here."
Julius Cæsar, Act II. Sc. I.

It must be remembered that these words were spoken on the Ides of March, or the 15th of that month, the day of Cæsar's assassination.

While speaking of the Sun's changing place of rising through the year, it may be well to note that Shakespeare knew the cardinal points of the compass, and made frequent mention of them:

"And truly I think if all our wits were to issue out of one skull, they would fly, *east, west, north, south,* and their consent of one direct way should be at once to all the points o' th' compass." Coriolanus, Act II. Sc. III.

Also Hamlet says:

"I am but mad north—north—west."
Hamlet, Act II. Sc. II.

I have spoken of the year as measured by the Sun's course through the zodiac. The divisions of time as used by Shakespeare, will now be further considered. He knew not only the chief divisions of time, but the instruments for its measurement,—clock, hour glass, dial.

Bernardo says to Francisco:

" 'Tis now struck twelve; get thee to bed Francisco."
Hamlet, Act I. Sc. I.

Helena says:

"Four and twenty times the pilot's glass
Hath told the thievish minutes how they pass."
All's Well That Ends Well, Act. II. Sc. I.

King Henry VI, thinking on the woes of this world, enumerates the divisions of time, and how he would like to fill them up with various employment away from the cares of his kingly state:

"O God! methinks it were a happy life
To be no better than a homely swain;
To sit upon a hill as I do now,
To carve out dials quaintly, point by point,
Thereby to see the minutes how they run,
How many make the hour full complete;
How many hours bring about the day;
How many days will finish up the year
How many years a mortal man may live."
Third Part Henry VI, Act II. Sc. V.

Then follows the different uses of time, and that splendid tribute to rural life, unequalled in our literature.

Closely associated with the subject of time is that of the seasons, months, and days of the week. The days of the week are used frequently by Shakespeare,—so frequently that no special instance of their use need be given here. I will give a few examples of his allusions to the months:

"Men are *April* when they woo, *December* when they wed: maids are *May* when they are maids, but the sky changes when they are wives."
As You Like It, Act IV. Sc. I.

Taking the same months again, the following passages are more characteristic:

"O, how this spring of love resembleth
The uncertain glory of an *April* day,
Which now shows all the beauty of the Sun,
And by and by a cloud takes all away!"
Two Gentlemen of Verona, Act I. Sc. III.

"Love, whose month is ever May,
Spied a blossom passing fair."
Love's Labor's Lost, Act IV. Sc. III.

"How like a winter hath my absence been
From thee, the pleasure of the fleeting year!
What freezings have I felt, what dark days seen!
What old *December's* bareness every where!
And yet this time remov'd was summer's time,
The teeming autumn, big with rich increase."
Sonnet XCVII.

Note how descriptive are the following lines on the months mentioned:

"What's the matter
That you have such a *February* face,
So full of frost, of storm and cloudiness?"
Much Ado About Nothing, Act V. Sc. IV.

"Proofs as clear as founts in *July* when
We see each grain of gravel."
Henry VIII, Act I. Sc. I.

"You sunburnt sicklemen, of *August* weary,
Come hither from the furrow and be merry:
Make holiday; your rye-straw hats put on
And these fresh nymphs encounter every one
In country footing." Tempest, Act IV. Sc. I.

The above quotations on the months partly describe the seasons; but let us notice Shakespeare's mention of the seasons a little further:

"Three winter's cold
Have from the forests shook three summer's pride,
Three beauteous springs to yellow autumn turn'd
In process of the seasons have I seen." Sonnet CIV.

So in Henry VI (Second Part) he speaks of—"Winter's cold and Summer's parching heat."

Titania imagines the dissensions of Oberon to have made the seasons change their usual appearances:

"The seasons alter; hoary-headed frosts
Fall in the fresh lap of the crimson rose,
And on old Hiems' thin and icy crown
An odorous chaplet of sweet summer buds
Is, as in mockery, set; the spring, the summer,
The chiding autumn, angry winter, change
Their wonted liveries."
Midsummer Night's Dream, Act II. Sc. I.

Calendar—Almanac. That Shakespeare knew the use of the calendar and almanac may be seen by these passages:

Enobarbus speaking of Cleopatra says:

"Her passions are made of nothing but the finest part of pure love; we cannot call her winds and waters sighs and tears; they are greater storms and tempests than *almanacs* can report."

Antony and Cleopatra, Act I, Sc. II.

Again this brief but interesting dialogue is to the point:

"Snout.—Doth the Moon shine that night we play our play?
Bottom.—A calendar, a calendar! look in the almanac; find out moonshine, find out moonshine.
Quince.—Yes, it doth shine that night."

Midsummer Night's Dream, Act III, Sc. I.

Astronomical terms. A few of the astronomical terms used by Shakespeare will now be noticed:

Zenith—This term is used once, and that in a more poetical than astronomical sense.

"I find my *Zenith* doth depend upon
A most auspicious star, whose influence
If now I court not but omit, my fortunes
Will ever after droop."

Tempest, Act I, Sc. II.

Antipodes—Shakespeare uses this word not less than five times. I will give two illustrations.

"Thou art as opposite to every good
As the *Antipodes* are unto us,
Or as the South to the Sepentrion."

Third Part Henry VI, Act I, Sc. IV.

"We should hold day with the *Antipodes*,
If you would walk in absence of the Sun."

Merchant of Venice, Act V, Sc. I.

Horizon—Meridian. Each of these terms is found but once.

"When the morning Sun shall raise his car
Above the border of this *horizon*,
We'll forward towards Warwick and his mates."

Third part Henry VI, Act IV, Sc. VII.

Cardinal Wolsey, fallen from the favor of Henry VIII, says,

"I have touched the highest point of all my greatness;
And, from that full *meridian* of my glory,
I haste now to my setting."

Henry VIII, Act III, Sc. III.

Further use of astronomical terms will appear under the various subjects treated.

Having shown some of the primary features of Shakespeare's general knowledge of astronomy, I will pass to the consideration of his special knowledge of the science. This brings us to his observations of the Sun, Moon, planets, etc.

The Sun. Shakespeare often refers to the Sun and under

various names,—Sol, Hyperion, and Phoebus. In the first passage below, it will be seen that he placed the Sun among the planetary bodies: and by reading the context, it will be further seen that he believed the Sun, with the other heavenly bodies revolved about the earth as a centre.

"Therefore is the glorious planet Sol
In noble eminence enthroned and sphered
Amidst the other."
Troilus and Cressida, Act I, Sc. III.

This passage will again be referred to in connection with the planets.

Henry V thinks the life of a slave preferable to the care-burdened life of kings. After reciting the pompous glories of kings, he says:

"Not all these, laid in bed majestical,
Can sleep so soundly as the wretched slave,
Who with a body fill'd with vacant mind
Gets him to rest, cramm'd with distressful bread,
Never sees horrid night, the child of hell,
But, like a lackey, from the rise to set
Sweats in the eye of *Phoebus*, and all night
Sleeps in Elysium; next day after dawn,
Doth rise and help *Hyperion* to his horse,
And follows so the ever-running year,
With profitable labor, to his grave.
Henry V, Act IV, Sc. I.

This same King Henry, in his courtship of Princess Katherine, employs the Sun with fine practical effect.

"A good heart, Kate, is the Sun and the Moon; or rather the *Sun* and not the Moon; for it shines bright and never changes, but keeps his course truly."
Henry V, Act V, Sc. II.

Richmond, on the evening before the battle of Bosworth Field, looks toward the west, and beholds a clear sunset. This gives him hope of a good day for his encounter with Richard III:

"The weary *Sun* hath made a golden set,
And, by the bright track of his fiery car,
Gives signal of a goodly day to-morrow."
Richard III, Act V, Sc. III.

Shakespeare understood, not only the general phenomena of the Sun's daily course, but some of its mysterious influences. For instance, the great evaporation of the sea by the Sun:

"The Sun's a thief, and with his great attraction
Robs the vast sea." Timon of Athens, Act IV, Sc. III.

In similar strain is the following passage in which Troilus speaks filled with envy and hatred of Diomed:

"Not the dreadful spout
Which shipmen do the hurricano call,
Constring'd in mass by the almighty Sun,
Shall dizzy with more clamor Neptune's ear
In his descent than shall my prompted sword
Falling on Diomed.
Troilus and Cressida, Act V, Sc. II.

The Moon. Shakespeare shows a varied knowledge of the Moon; and for one whose vocation was writing plays for the stage, we may say his knowledge was extensive.

He puts the main facts about the Moon into his writings, often in a very striking manner.

Of course, he did not neglect to speak of the fanciful notions about the Moon—as the old tradition of the man in the Moon. This is mentioned several times. I will give but one reference:

"Caliban.—Hast thou not dropp'd from heaven?
Stephano.—Out o' the Moon I do assure thee; I was the man i' the Moon when time was." Tempest, Act II, Sc. II.

The Moon's age is pointedly expressed:

"The Moon is never but a month old."
Love's Labor's Lost, Act IV, Sc. II.

Also her changes through the month:

"*Rosaline.*—Not yet! No dance! Thus change I like the Moon.
King.—Will you not dance? How come you thus estranged?
Rosaline.—You took the Moon at full but now she's changed."
Love's Labor's Lost, Act V, Sc. II.

"You would lift the Moon out of her sphere, if she would continue in it five weeks without changing." Tempest, Act II, Sc. I.

The horns of the Moon and her crescent and waning phases are mentioned:

"They threw their caps
As they would hang them on the *horns o' the Moon,*
Shouting their emulation."
Coriolanus, Act I, Sc. I.

So in this dialogue:

"*Moonshine.*—This lanthorn doth the horned Moon present.
Demetrius.—He should have worn the *horns* on his head.
Theseus.—He is no *crescent*, and his horns are invisible within the circumference.
* * * * *
Hippolyta.—I am aweary of this Moon: would he would change!
Theseus.—It appears by his small light of discretion, that he is in the *wane.*"
Midsummer Night's Dream, Act V, Sc. I.

Shakespeare shows clearly that he knew the light of the Moon is simply reflected sunlight:

"The Moon's an arrant thief,
And her pale fire she snatches from the Sun."
Timon of Athens, Act. IV, Sc. III.

Also note this conversation:

"*Alcibades*—How came the noble Timon to this change?
Timon—As the Moon does by wanting life to give:
But then renew I could not, like the Moon;
There were no suns to borrow of."
Timon of Athens, Act IV, Sc. III.

Thersites expresses Diomed's false-heartedness by a striking comparison with the Moon's borrowed light—only by an *absurdum* method:

"That same Diomed's a false-hearted rogue,
a most unjust knave * * * *
The Sun borrows of the Moon, when
Diomed keeps his word."
Troilus and Cressida, Act V, Sc. II.

Not less interesting are Shakespeare's references to the Moon's influence on the sea.

"The Moon, *the governess of floods*,
Pale in her anger, washes all the air."
Midsummer's Night's Dream, Act II, Sc. I.

"You may as well
Forbid the sea for to obey the Moon
As or by oath remove or counsel shake
The fabric of his folly."
Winter's Tale, Act I, Sc. II.

Directly to the point is the following talk between Falstaff and Prince Henry:

"Falstaff.—Let men say we be men of good government, being governed, as the sea is, by our noble and chaste mistress the Moon, under whose countenance we steal.
Prince.—Thou say'st well, and it holds well too; for the fortune of us that are the Moon's men doth ebb and flow like the sea, being governed, as the sea is, by the Moon."
First part Henry IV, Act I, Sc. II.

No passages illustrating Shakespeare's knowledge of astronomy, are more significant than the lines in which he describes the Moon's condition:

Thesens says to Hermia,

"You can endure the livery of a nun,
For aye to be in shady cloister mew'd,
To live a barren sister all your life,
Chanting faint hymns to the *cold fruitless Moon.*"
Midsummer Night's Dream, Act I, Sc. I.

And Oberon says to Puck,

"That very time I saw, but thou could'st not,
Flying between the *cold* Moon and the Earth,
Cupid all arm'd."
Midsummer Night's Dream, Act II, Sc. I.

The two passages last quoted show a higher degree of prophecy with regard to the discoveries of modern science than any other passages in Shakespeare.

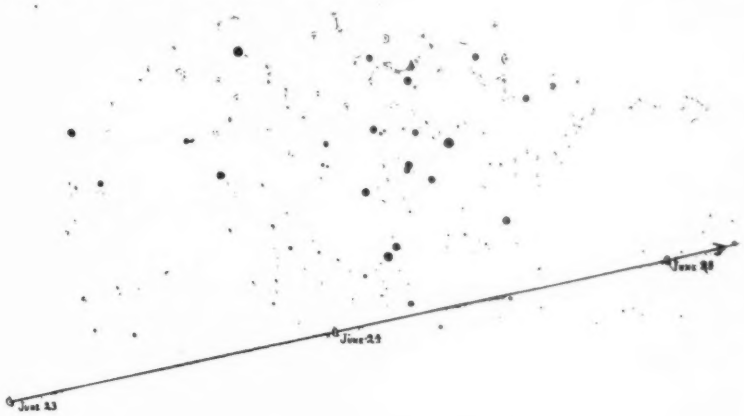
Perhaps no fact concerning the Moon is better established than that the Moon is "cold and fruitless;" and Shakespeare going beyond the knowledge of his time, looked into the future and with a prophet's voice uttered the conclusions of modern science with remarkable precision.

Eclipses of the Sun and Moon will be noticed under the subject of astrology. (TO BE CONTINUED).

PLANET NOTES FOR JUNE.

H. C. WILSON.

Mercury begins the month a little way past greatest western elongation, on its journey around to the rear of the Sun. It will reach superior conjunction on the morning of June 30. It will therefore be morning planet all the month but will be in unfavorable position to be seen.



VENUS PASSING THE PRAESEPE CLUSTER.

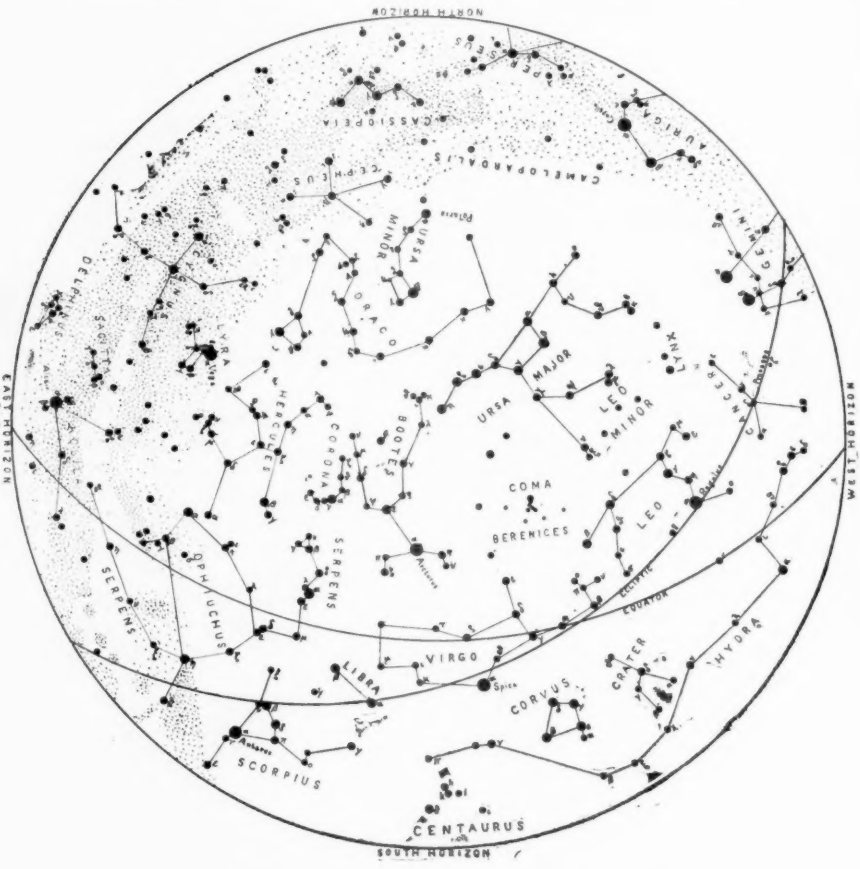
Venus none can fail to see in the western sky from eight to nearly ten o'clock in the evening. She has attained only about one-third of her maximum brilliancy but even now she far outshines any of the neighboring stars. Venus is passing the constellation Gemini to the south of the twin stars Castor and Pollux. Later she will pass through Cancer, skirting the north edge of the Præsepe cluster and possibly occulting some of its stars on the evening of June 24. The crescent Moon and Venus will be in conjunction, the latter 3° 18′ to the north of the former, on the evening of June 21 just as the two are near the western horizon.

Mars will pass through Aries this month, being visible in the morning. His semidiameter is only 5″ so that not much of detail can be seen upon his surface.

Jupiter is almost stationary between β and η Virginis but will move slowly eastward during the month. He is near the meridian at seven o'clock in the even-

ing at an altitude of 46°. The twilight hours are the best for study of the planet's surface. Even before the Sun sets good views may be obtained.

Saturn must have been noticed by many of our readers during the clear evenings of the past month. His golden light is quite conspicuous in contrast with the ruddy hue of Antares in Scorpio. Saturn was at opposition May 30, so that the best time for observation now is the hour before midnight. The rings are now turned at an angle of nearly 26° to the line of sight so that they are comparatively open and the Cassini division and the "crape" ring can be easily seen.



THE CONSTELLATIONS AT 9 P. M., JUNE 1, 1898.

Uranus, about 1° west and 43′ south of the star β Scorpio, is in most convenient position for evening observation but at a rather low altitude for satisfactory views. Its dull green disk is easily distinguished from the vivid diskless stars.

Neptune is behind the Sun, being at conjunction June 12.

The Moon.

		Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.)		Sets.	
			h	m	h	m
June	4	Full Moon	8	37 P. M.	5	10 A. M.
	11	Last Quarter	11	49 "	11	37 "
	18	New Moon	3	42 A. M.	8	2 P. M.
	26	First Quarter	12	2 P. M.	11	35 "

Occultations Visible at Washington.

Date 1898.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
June	3	σ Scorpii	3.4	7	26	116	8	21	317	0	53
	5	B.A.C. 6369	6.2	11	22	125	12	18	220	0	56
	8	λ Capricorni	5.7	13	12	125	13	44	179	0	32
	14	μ Arietis	6.0	15	15	73	16	16	283	1	1
	16	62 Tauri	6.0	14	59	108	15	44	226	0	45
	30	A^2 Scorpii	5.2	8	55	131	10	5	255	1	10
	30	3 Scorpii	6.7	9	21	101	10	41	280	1	20

Phenomena of Jupiter's Satellites.

Central Standard Time.

		h	m					h	m		
June	1	7	6 P. M.	I	Tr. In.	June	16	8	00 P. M.	I	Oc. Dis.
		8	18 "	I	Sh. In.		17	7	36 "	I	Tr. Eg.
		9	21 "	I	Tr. Eg.			7	17 "	III	Tr. In.
		10	33 "	I	Sh. Eg.			8	52 "	I	Sh. Eg.
	2	8	39 "	I	Ec. Re.		20	7	38 "	II	Sh. In.
		10	41 "	II	Tr. In.			7	39 "	II	Tr. In.
	3	8	11 "	III	Sh. Eg.			10	8 "	II	Sh. Eg.
	4	10	45 "	II	Ec. Re.		23	9	54 "	I	Oc. Dis.
	7	11	38 "	I	Oc. Dis.		24	7	15 "	I	Tr. In.
	8	8	58 "	I	Tr. In.			8	32 "	I	Sh. In.
		10	13 "	I	Sh. In.			9	31 "	I	Tr. Eg.
		11	14 "	I	Tr. Eg.			10	46 "	I	Sh. Eg.
	9	9	34 "	I	Ec. Re.		25	7	52 "	I	Ec. Re.
	10	7	16 "	III	Tr. Eg.		27	7	39 "	II	Tr. In.
		9	34 "	III	Sh. Eg.			10	14 "	II	Sh. In.
	11	8	20 "	II	Oc. Dis.			10	15 "	II	Tr. Eg.
		10	56 "	II	Oc. Re.		28	7	40 "	III	Ec. Dis.
		10	56 "	II	Ec. Dis.			10	0 "	III	Ec. Re.
	13	7	33 "	II	Sh. Eg.		29	7	51 "	II	Ec. Re.
	15	10	52 "	I	Tr. In.						

Ec. Dis. = Eclipse disappearance; Ec. Re. = Eclipse reappearance; Oc. Dis. = Occultation disappearance; Oc. Re. = Occultation reappearance; Sh. In. = Ingress of shadow upon disc of planet; Sh. Eg. = Egress of shadow from disc; Tr. In. = Ingress of satellite in transit across disc of planet; Tr. Eg. = Egress of satellite.

Jupiter's Satellites for June.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.

III.

II.

IV. No Eclipse

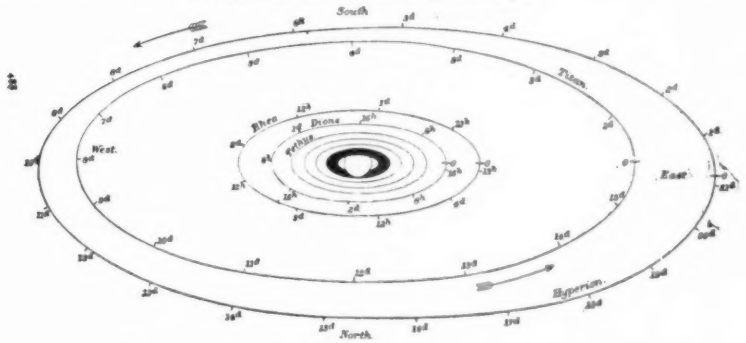
Configuration at 9h 00m for an Inverting Telescope.

Day.	West.	East.
1	○ 1· 4·	○ ·2 3·
2	4·	○ 2· ·1 3·
3	4· 2· 1· 3·	○
4	4· 3·	○ ·2 ·1
5	·4 ·3 ·1	○ 2·
6	·4 2· ·3	○ 1·
7	·4 ·2 ·1	○ ·3
8	○ 1· ·4	○ ·2 ·3
9		○ ·1 2· ·4 3·
10	2· 1· 3·	○ ·4
11	3·	○ ·1 ·4 ·2●
12	·3 1·	○ 2· ·4
13	·3 2·	○ 1· 4·
14	·2 ·1	○ ·3 4·
15		○ 1· ·2 ·3 4·
16		○ 2· 4· 3· ·1●
17	○ 3· 2· 1· 4· ○	
18	3· 4· ·2 ○	·1
19	4· ·3 1·	○ ·2
20	4· ·3 2· ○	1·
21	4· ·2 ·1	○ ·3
22	·4	○ 1· ·2 ·3
23	·4 ·1 ○	2· 3·
24	○ 1. ·4 2·	○ 3·
25	3· ·2 ·4 ○	·1
26	·3 1·	○ ·4 ·2
27	○ 2· ·3	○ ·1 ·4
28	·2 ·1	○ ·3 4·
29		○ ·21· ·3 ·4
30	·1	○ 2· 3· 4·

Saturn's Satellites.

[The diagram indicates the position of the outer satellites of Saturn at intervals of 1 day, after greatest eastern elongation. The ephemeris below gives the Central Standard times when the satellites will be at either eastern elongation (E) or western elongation (W), or, in the case of the outermost ones, inferior conjunction, south of the planet, (I) and superior conjunction, north of the planet, (S).]

APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, at opposition in 1898, as seen in an inverting telescope.



I. MIMAS.

Period $0^d\ 25^h.6$

		h		
June	1	9.9	P. M.	W
	2	8.5	"	W
	3	7.2	"	W
	7	2.3	A. M.	E
	8	12.9	"	E
	8	11.5	P. M.	E
	9	10.1	"	E
	10	8.8	"	E
	11	7.4	"	E
	16	1.1	A. M.	W
	16	11.7	P. M.	W
	17	10.4	"	W
	18	9.0	"	W
	19	7.6	"	W
	24	1.3	A. M.	E
	24	12.0	MIDN.	E
	25	10.6	P. M.	E
	26	9.2	"	E
	27	7.8	"	E

II. ENCELADUS.

Period $1^d\ 8^h.9$

		h		
June	1	3.3	P. M.	E
	2	12.2	A. M.	E
	4	9.1	"	E
	5	5.9	P. M.	E
	7	2.8	A. M.	E
	8	11.7	"	E
	9	8.6	P. M.	E
	11	5 5	A. M.	E
	12	2.3	P. M.	E
	13	11.2	"	E
	15	8.1	A. M.	E
	16	5.0	P. M.	E
	18	1.8	A. M.	E
	19	10.7	A. M.	E
	20	7.6	P. M.	E
	22	4.5	A. M.	E

II. ENCELADUS CON.

Period $1^d\ 8^h.9$

	h		
23	1.3	P. M.	E
24	10.2	"	E
26	7.1	A. M.	E
27	4.0	P. M.	E
29	12.9	A. M.	E
30	9.7	"	E

III. TETHYS.

Period $1^d\ 21^h.3$

		h		
June	1	12.3	P. M.	E
	3	9 6	A. M.	E
	5	6.9	"	E
	7	4.2	"	E
	9	1.5	"	E
	10	10.7	P. M.	E
	12	8 0	"	E
	14	5.3	"	E
	16	2.6	"	E
	18	11.9	A. M.	E
	20	9.2	"	E
	22	6.5	"	E
	24	3.8	"	E
	26	1.1	"	E
	27	10.4	P. M.	E
	29	7.7	"	E

IV. DIONE.

Period $2^d\ 17^h.7$

		h		
June	2	10.1	P. M.	E
	5	3.7	"	E
	8	9.4	A. M.	E
	11	8.0	"	E
	13	8.7	P. M.	E
	16	2.3	"	E
	19	7.9	A. M.	E
	22	1.6	"	E

IV. DIONE CON.

Period $2^d\ 17^h.7$

		h		
	24	7.3	P. M.	E
	27	12.9	"	E
	30	6.6	A. M.	E

V. RHEA.

Period $4^d\ 12^h.5$

		h		
June	4	12.5	A. M.	E
	8	12.8	P. M.	E
	13	1.2	A. M.	E
	17	1.5	P. M.	E
	22	1.8	A. M.	E
	26	2.1	P. M.	E
July	1	2.5	A. M.	E

VI. TITAN.

Period $15^d\ 23^h.3$

		h		
June	4	7	A. M.	S
	8	3	"	E
	12	2	"	I
	16	5	"	W
	20	4	"	S
	24	1	"	E
	28	12	"	I

VII. HYPERION.

Period $21^d\ 7^h.6$

	d			d	
June	2.6	W	June	19.1	I
	7.9	S		23.9	W
	13 7	E		29.2	S

VIII. JAPETUS.

Period $79^d\ 22^h.1$

June 4.3 E June 23.0 I
July 13.2 W

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

1898 August.

MAXIMA.

		m	day
112	R Andromedæ	7	16
678	U Persei	7.5	31:
715	S Arietis	9.5	8
1635	R Reticuli	7	5
2478	R Lyncis	8	20
2583	L Puppis	3.5	31
2684	S Canis minoris	7.5	22
2780	T Geminorum	8.5	18:
3170	S Hydræ	8	20
3477	R Leonis minoris	7	12
3493	R Leonis	6	17
4940	W Hydræ	6.5	15
5095	R Centauri	6	22
5157	S Bootis	8	21
5494	S Libræ	8	27
5511	RS Libræ	8	3
5770	R Herculis	8.5	24
5776	X Scorpii	10	21
6170	RW Scorpii	9.5	6:
6943	T Sagittæ	8.5	25:
7077	T Pavonis	7.5	28
7085	RT Cygni	7	25
7428	V Cygni	8	12
7468	T Aquarii	7.5	16
7571	V Capricorni	9	21
7577	X Capricorni	10	25
7733	Y Capricorni	10.5	26
7779	S Cephei	8.5	7

MINIMA.

		m	day
62	S Sculptoris	10	—
107	T Cassiopeæ	11.5	8
267	V Andromedæ	< 12	—
782	R Arietis	12	7
976	T Arietis	9.5	10
1623	T Camelopard.	< 12	4:
2258	V Aurigæ	< 11	13:
2625	V Geminorum	13	20
2946	R Cancri	< 11	12:
2976	V Cancri	< 12	24
3994	S Leonis	< 13	12:
5617	U Libræ	< 14	—
5831	S Scorpii	< 13	—
5903	Y Scorpii	14	—
6207	Z Ophiuchi	12	11:
6512	T Herculis	11	31
6921	S Sagittarii	14.5	19:
7242	S Aquilæ	11	8
7450	V Aquarii	9.5	—
7590	Z Capricorni	11.5	—
8230	S Aquarii	< 12	—
8324	V Cassiopeæ	12	21:
8597	V Ceti	14	—
8600	R Cassiopeæ	10	22
8622	W Ceti	12	—

The authorities for the above ephemeris are the same as in the previous numbers of the present year.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1898.

U CEPHEI.

	d	h
July	5	11
	10	11
	15	11
	17	22
	20	10
	22	22
	25	10
	27	22
	30	9

ALGOL.

July	2	19
	5	16
	8	13
	22	21
	25	18
	28	14

δ LIBRAE.

	d	h
July	7	13
	14	13
	21	12
	28	12

U CORONÆ.

July	8	19
	15	16
	22	14
	29	12

U OPHIUCHI.

Every 10th min.

P = 20h.1

July	6	11
	14	21
	23	6
	31	15

RS SAGITTARII.

	d	h
July	3	17
	8	13
	13	9
	15	19
	20	15
	25	11
	27	21

W DELPHINI.

July	6	19
	11	14
	16	10
	30	20

Y CYGNI.

Even min.

July	1	11
	4	11
	7	11
	10	11
	13	11
	16	11
	19	11
	22	10
	25	10
	28	10
	31	10

Odd min.

July 2 14 and every three days to July 29 14

Z HERCULIS. According to Dunér's revised elements in *Astronomical Journal* No. 422, the even, or "principal" minima of this star cannot be observed in America at present, though they are visible in Europe, while the odd, or "secondary" minima can be but partially observed in America. The following data are extracted from his article:

Even Minima.						Odd Minima.					
Epoch.		Date.	d	h	m	Epoch.		Date.	d	h	m
2786	1898	May	14	12	26.1	2785	1898	May	12	16	0.8
2806		June	13	11	34.8	2805		June	11	15	6.8
2826		July	13	10	43.5	2825		July	11	14	12.8

Period, for even minima, $1^d.498219 = 1^d\ 11^h\ 57^m.4$
" " odd " $1\ .498124 = 1\ \ 11\ \ 57\ .3$

"A NEW VARIABLE OF PRESUMABLY VERY LONG PERIOD." In a note with this title in *Astronomical Journal* No. 434, Professors Müller and Kempf, of Potsdam, call attention to the star B. D. + 30°,591 and give the following mean magnitudes from 160 observations:

	No. of obs.	M
1888 Feb. 25—1891 Feb. 13	50	6.31
1893 Nov. 9—1894 Mar. 24	5	6.44
1895 Feb. 8—1895 Apr. 2	9	6.60
1895 Sept. 26—1896 Apr. 2	41	6.69
1896 Aug. 28—1897 Apr. 9	28	6.82
1897 Aug. 18—1898 Mar. 20	26	6.92

The note closes with the remark "Presumably we have here to deal with a binary system, in which one star is at present transiting across the other."

The position of this star for 1855 is:

R. A. $3^h\ 46^m.3$, Decl. + 30° 38′.

The progressive change in magnitude, though slight: is placed beyond doubt by the excellence of the photometric work of Professors Müller and Kempf.

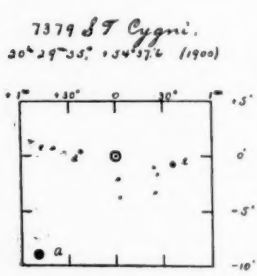
It is possible that a similar explanation will account for the mystery attaching to Deichmüller's variable which was charted in POPULAR ASTRONOMY for Dec. 1897, page 437. As noted there, this star was found $9^m.0$ by the DM. observers in 1856, was missed by the Leyden observers in 1871 and 1893, therefore less than $9^m.5$, and was found $8^m\ 9$ by Professor Deichmüller 1897 Sept. 11. I have watched it carefully since 1897 Oct. 9 and found it stationary at about $9^m.0$ up to the present time.

NOTATION OF RECENTLY DISCOVERED VARIABLES. In No. 433 of the *Astronomical Journal* Dr. Chandler assigns the following notations:

	1900				1855			
	R. A.		Decl.		R. A.		Decl.	
	h m s		° ′		h m s		° ′	
2376 S Lyncis	6 35 56		+ 58	0.5	6 32 3		+ 58	2.8
6899 U Draconis	19 9 57		+ 67	6.9	19 9 54		+ 67	2.4
7379 ST Cygni	20 29 55		+ 54	37.6	20 28 44		+ 54	28.5

S Lyncis is charted in the April number of this magazine, page 118 and its duplicity noted in the May number, page 185. U Draconis is charted in the February number, page 556. It is now (last observation May 7) fainter than the 12.5 magnitude.

ST Cygni, of which a small chart is here given, proves to be a remarkable



star. It is Espin 911, and was announced as variable, from 9 to 14 magnitude, in Wolsingham Observatory Circular No. 44. Espin found it $9^m.3$ 1893 Sept. 30 and less than 15^m 1897 Dec. 11. I found nothing as bright as the 12th magnitude in the place 1898 Jan. 27. The variable appeared in February and gradually rose to about 9^m in April. The comparison star *a* is DM. + 54°,2374, $6^m.6$, *c* and *d* are about 10^m.

U GEMINORUM. The following observations are at hand for the maximum just passed, D standing for Zaccheus Daniel and P for J. A. Parkhurst.

1898 Gr. Time.			
Apr. 26.60		V not seen, less than $13^m.3$	P
May 4 57		V not seen, less than 10 .8	D
7.56		$9^m.8$ good	D
7.58	9 .85	fair, twilight	P
8 54	9 .85	good	D
9.54	10 .0	poor, haze	D
11.59	11 .0	fair	P
12.57	12.6		D

The maximum evidently occurred between May 4 and 7. A comparison with POPULAR ASTRONOMY Vol. V, page 17 will show that this was a "short" maximum, and if the star followed the typical curve there given the maximum was passed about May 6.0. If this is true the interval since the last maximum is 87 days, very near the mean period.

J. A. PARKHURST.

COMET NOTES.

Elliptic Elements of Comet *b*, 1898.—Using the following observations of this comet I computed a set of parabolic elements as below:

1898	Mt. Hamilton M. T.			App. α			App. δ		
	h	m	s	h	m	s	°	′	″
March 19,	16	47	21	21	18	36.89	+ 16	43	23.3
April 8,	16	19	7	22	41	0.88	+ 36	20	50.5
April 28,	15	26	54	0	23	20.68	+ 49	41	32.4

$$T = 1898 \text{ March } 17,35984.$$

	°	′	″	
ω =	47	36	8.0	1898.0
Ω =	262	32	26.3	
i =	72	26	50.4	

$$\log q = 0.040820$$

The residuals from these elements for the middle place are:

Observed — Computed	$\Delta \lambda' \cos \beta'$	− 14.″7
	$\Delta \beta'$	+ 22. 4

From the same three observations I then obtained the following system of elliptic elements:

Epoch 1898 March 20.0

	°	′	″	
M =	0	0	34.1	
ω =	47	14	48.8	1898.0
Ω =	262	24	42.9	
i =	72	32	55.8	

$\log q = 0.039179$
" $a = 1.656386$
" $e = 9\ 989386$
" $\mu = 1.065428$
$\mu = 11.''62595$
Period = 305.208 years.
$\varphi = 77° 23' 3''.5$

The residuals for the three places used are

	α	δ
Observed—Computed	$-1''.2$	$+1''.1$
	$-0\ .3$	$-1\ .2$
	$+0\ .5$	$+1\ .1$

The constants for the equator of 1898.0 are

$$x = r\,[9.512253]\ \sin(\ 23\ \ 17'\ \ 43.4'' + v)$$
$$y = r\,[9\ 999997]\ \sin(292\ \ 39'\ \ 52.2'' + v)$$
$$z = r\,[9.975717]\ \sin(\ 22\ \ 35'\ \ 22.6'' + v)$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1898		True α			True δ		log. r	log. Δ	Br.
		h	m	s	°	′			
May	17.5	2	2	43	+ 55	10.8	0.1649	0.3188	0.33
	19.5		12	54		27.5			
	21.5		22	49		41.5	0.1768	0.3308	0.29
	23.5		32	31	+ 55	52.9			
	25.5		41	59	+ 56	1.9	0.1885	0.3422	0.26
	27.5	2	51	13		8.5			
	29.5	3	0	12		13.1	0.2002	0.3532	0.24
	31.5		8	57		16.3			
June	2.5		17	27		17.9	0.2117	0.3638	0.21
	4.5		25	42		17.8			
	6.5		33	43		16.3	0.2231	0.3738	0.19
	8.5		41	29		13.6			
	10.5		49	1		9.8	0.2343	0.3733	0.18
	12.5	3	56	18		5.3			
	14.5	4	3	21	+ 56	0.0	0.2454	0.3922	0.16
	16.5		10	11	+ 55	53.7			
	18.5		16	47		46.9	0.2562	0.4005	0.15
	20.5		23	11		39.6			
	22.5		49	22		31.8	0.2668	6.4083	0.14
	24.5		35	21		23.8			
	26.5	4	41	7	+ 55	15.4	0.2773	0.4154	0.13

The brightness at discovery is taken as unity.

Comet *b* 1898 and its Resemblance to the Comets of 1684 and 1785 I.—Upon looking over the elements of some of the older comets, after finding comet *b* to be periodic, I have been interested in a certain family resemblance between it and those of 1684 and 1785 I. For reference I append the elements of all three:

	ϖ °	Ω °	i °	q
1684	330.3	268.2	65.4	0.958
1785 I	205.7	264.2	70.2	1.143
1898 (*b*)	47.6	262.5	72.4	1.094

The comet of 1684 was visible but a short time, and the orbit is based upon the interval July 1 to 17, 1684. This short arc and the crude methods of such observations in those early days renders the orbit somewhat uncertain.

The comet of 1785 was visible five weeks and the orbit should be more reliable than that of 1684.

Precession when applied to the older comets does not on the whole bring them into better agreement—just the contrary being the case with ☊. The resemblance of ☊, i and q is sufficiently close to be striking, especially when taken into account with the fact that the present comet is undoubtedly periodic, with a long period. It hardly seems as if the present comet's period would be shortened to anything like one hundred years. It is, however, a little suspicious that the intervals are about one hundred years. The great discrepancies in ω are rather against any identity, but it is to be noticed that ω varies in the same direction. It would seem from our present knowledge of the orbits of these bodies that they rather belong to the same family than that they are one and the same body.

C. D. PERRINE.

Lick Observatory, University of California,
1898, May 9.

Ephemeris of Wolf's Periodic Comet.—Dr. A. Thraen gives, in *Astronomische Nachrichten* No. 3481, elements of Wolf's periodic comet, depending upon the observations of 1884 and 1891-2, brought down to date and corrected for the perturbations by the planets.

EPOCH AND OSCULATION AUG. 22.0, 1898, BERLIN MEAN TIME.

$M = 6° 58' 11''.03$
$\pi = 19 21 38 .41$
$\Omega = 206 29 3 .89$ } Mean equinox 1900.0
$i = 25 12 15 .77$
$\varphi = 33 44 2 .15$
$\mu = 518''.36764$
$\log a = 0.5569125$

EPHEMERIS.

1898	α h	m	s	δ °	′	log r	log Δ	Ab. Time m	s	Brightness
June 3	1	36	19	+ 18	33.0	0.2131	0.3402	18	10	1.68
11	1	59	58	19	19.0	0.2095	0.3300	17	44	1.80
19	2	23	48	19	51.3	0.2069	0.3198	17	20	1.90
27	2	47	43	20	8.7	0.2054	0.3099	16	56	2.01
July 1	2	59	39	20	11.2	0.2050	0.3048	16	45	2.06
5	3	11	32	20	10.2	0.2049	0.2999	16	33	2.11
9	3	23	22	20	4.6	0.2051	0.2950	16	22	2.15
13	3	35	7	19	54.9	0.2056	0.2901	16	11	2.20
17	3	46	44	19	40.9	0.2064	0.2853	16	0	2.24
21	3	58	15	19	22.7	0.2074	0.2804	15	49	2.28
25	4	9	35	19	0.2	0.2087	0.2756	15	39	2.31
29	4	20	45	+ 18	33.4	0.2102	0.2707	15	29	2.35

The comet will be in a very unfavorable position to be found, being seen only in the morning twilight. The unit of brightness is that which the comet possessed on May 1, 1891, when it was invisible in most telescopes.

Ephemeris of Encke's Periodic Comet.—No. 3490 of the *Astronomische Nachrichten* contains an ephemeris by A. Iwanow, for the next apparition of Encke's comet which is now due. The elements for 1898 corrected for the perturbations by Jupiter are as follows:

EPOCH MARCH 25.0 BERLIN TIME.

$M = 341°\ 14'\ 55''.16$
$\pi = 158\ 45\ 39\ .44$
$\Omega = 334\ 46\ 42\ .79$ } 1898.0
$i = 12\ 54\ 36\ .93$
$\varphi = 57\ 49\ 14\ .75$
$\mu = 1074''.29183$

The ephemeris is not likely to be more than 3′ in error.

1898		α			δ			log r	log δ	Aber. Time.	
		h	m	s	°	′				m	s
June	1	6	7	12	+ 20	15	.5	9.5657	9.9496	7	20
	2		12	13	19	36	.2	.5784	.9345	7	7
	3		16	58	18	55	.0	.5919	.9191	6	54
	4		21	32	18	12	.1	.6065	.9036	6	39
	5		25	54	17	27	.5	.6216	.8879	6	25
	6		30	8	16	41	.0	.6371	.8721	6	11
	7		34	13	15	52	.9	.6526	.8562	5	58
	8		38	13	15	2	.9	.6683	.8402	5	46
	9		42	9	14	10	.8	.6837	.8241	5	33
	10		46	3	13	16	.6	.6991	.8079	5	21
	11		49	55	12	20	.2	.7141	.7916	5	9
	12		53	48	11	21	.4	.7289	.7753	4	58
	13	6	57	42	10	20	.0	.7432	.7588	4	46
	14	7	1	41	9	15	.8	.7572	.7422	4	36
	15		5	14	8	8	.2	.7709	.7255	4	25
	16		9	55	6	57	.3	.7842	.7087	4	15
	17		14	14	5	42	.8	.7971	.6918	4	5
	18		18	43	4	24	.2	.8097	.6748	3	56
	19		23	24	3	1	.0	.8218	.6578	3	47
	20	7	28	18	1	33	.4	.8335	.6408	3	38
	21		33	29	+ 0	0	.2	.8450	.6237	3	30
	22		38	59	− 1	38	.7	.8562	.6067	3	22
	23		44	48	3	23	.5	.8671	.5898	3	14
	24		51	0	5	14	.8	.8776	.5731	3	7
	25	7	57	38	7	12	.1	.8878	.5565	3	0
	26	8	4	46	9	16	.8	.8977	.5405	2	54
	27		12	26	11	28	.8	.9074	.5248	2	47
	28		20	41	13	47	.5	.9167	.5099	2	42
	29		29	38	16	13	.7	.9258	.4958	2	36
	30		39	19	18	45	.8	.9347	.4826	2	32
July	1	8	49	51	− 21	23	.9	9.9435	9.4708	2	27

Ephemeris of Winnecke's Periodic.—This comet has been observed for some time at the present apparition. The ephemeris for June by C. Hillebrand is as follows:

1898		α			δ		log r	log δ	$1 : r^2\Delta^2$
		h	m	s	°	′			
June	1	1	51	14	− 1	22.2			
	3	1	56	4	1	7.0	0.1487	0.2714	0.14
	5	2	0	48	0	52.3			
	7	2	5	26	0	38.3	0.1604	0.2754	0.13
	9	2	9	59	0	24.9			
	11	2	14	26	0	12.2	0.1719	0.2788	0.13
	13	2	18	47	− 0	0.1			
	15	2	23	3	+ 0	11.4	0.1832	0.2817	0.12
	17	2	27	13	0	22.2			
	19	2	31	17	+ 0	32.3	0.1942	0.2841	0.11

Search Ephemeris for Tempel's Periodic Comet (1867 II).

[Computed by R. Gautier, *Astronomische Nachrichten*, No. 3492.]

		R. A.			Decl.		log Δ	log r
		h	m	s	°	′		
June	1	11	41	11	+ 13	50.1		
	3		42	37	+ 13	27.6	0.2828	0.3578
	5		44	8	+ 13	4.7		
	7		45	44	+ 12	41.3	0.2903	0.3556
	9		47	25	+ 12	17.5		
	11		49	10	+ 11	53.4	0.2977	0.3535
	13		51	0	+ 11	28.9		
	15		52	55	+ 11	4.1	0.3050	0.3515
	17		54	54	+ 10	38.9		
	19		56	57	+ 10	13.4	0.3122	0.3495
	21	11	59	5	+ 9	47.6		
	23	12	1	16	+ 9	21.4	0.3193	0.3475
	25		3	31	+ 8	55.0		
	27		5	50	+ 8	28.3	0.3262	0.3456
	29		8	13	+ 8	1.3		
July	1	12	10	49	+ 7	34.1	0.3330	0.3437

The comet is at a great distance from the Earth and will be exceedingly faint. Observers who have powerful telescopes are requested to search carefully for it near the ephemeris place. The errors of the ephemeris are not likely to be greater than 1° 10′ in declination and 12^m in right ascension at a maximum estimate.

The orbit has been considerably changed by the perturbations of Jupiter since 1879, when it was last seen. The perihelion distance has been increased from 1.56 in 1867 to 2.069 in 1892 and slightly more since that time, so that the comet is much less favorably situated for observation. The latest elements are:

Epoch April 4.0 1898 Berlin mean time.

$M = 332°\ 25'\ 25''.28$
$\pi = 241\ 16\ 57\ .6$ } 1898.0 $\varphi = 23°\ 43'\ 0''.4$
$\Omega = 72\ 36\ 53\ .0$ } 1898.0 $\mu = 542''.38726$
$i = 10\ 47\ 7\ .6$ } $T = 1898$ Oct. 4.0116 B. M. T.

GENERAL NOTES.

We are unable to present some matter intended for this issue, because of the failure of the plates to accompany the articles.

Subscribers will please bear in mind that this publication will close its sixth volume with the December number of this year, and that volumes of ten numbers each, thereafter, will be issued annually, beginning in January of each year.

Spectrum of *o* Ceti.—Some beautiful spectra of the variable, *o* Ceti, were photographed in November and December, 1897, at the Stonyhurst College Observatory, England, by Rev. W. Sidgreaves. Drawings were made from the photographs, and excellent reproductions of the drawing are given in the April No. of the Monthly Notices of the Royal Astronomical Society, Vol. 58, No. 6.

Lantern Slides for High Schools.—It has occurred to us, that it would be a most helpful thing, to prepare about 300 astronomical lantern slides covering the six classes of celestial bodies for the purpose of illustrating the principal

points relating to them to aid teachers in High schools and Academies in giving better instruction in the elements of astronomy. Such a set of slides would furnish illustration enough for a course of lectures covering ten or twelve hours, and would certainly awaken a popular interest, that probably could not be secured so well in any other way.

The six classes of the heavenly bodies referred to above, are the Moon, Sun, planets, comets, stars and the nebulæ. The teacher who would prepare himself to deliver such a course, will certainly find it one of the best ways of fitting himself for good work as a teacher that he could pursue.

The Second Moon to Earth.—So good a paper as the *Popular Science News* has nearly a column article, in regard to a second Moon to the Earth. That which will interest astronomers about this second Moon is the alleged fact that its orbit has been computed. Its distance from Earth is 640,000 miles; its diameter is 435 miles. It is faint generally, and can be seen only by the aid of a large telescope. "Sometimes," says Dr. Waltemath "it shines at night like a Sun," and he thinks Lieut. Greely, when in Greenland in 1881, saw this little Moon, and by mistake regarded it as the Sun. though it was ten days after the time when our Sun should have been invisible, and this fact was what puzzled Lieut. Greely. But Dr. Waltemath makes all plain when he says that Lieut. Greely saw this little Moon and mistook it for our Sun out of place.

That is a very good one for Lieut. Greely. It is the best joke of the season surely! It is not probable, at all, that *anyone* having *any* knowledge of the elements of astronomy would be mislead by such statements.

Observations on Venus at the Lowell Observatory.—Since Venus has returned to a favorable position we have resumed our observations of the form and detail of that planet. I had previously made very few drawings, but a few weeks ago my interest was suddenly aroused by viewing the planet when a diaphragm was being used, reducing the affective aperture of the lens to about three inches—the very condition which Mr. Drew had been using for many months. Detail was evident at the very first glance and I found myself depicting successfully and with ease some characteristic details which Mr. Lowell represents on his map.

In order to test the reality of the appearances the telescope was reversed but the detail remained the same; the head was turned in different positions, the eyepieces were twisted, other eyepieces and two other objectives and other diaphragms even as small as 1.6 inch were tried with unchanged result. Finally my drawings were found to agree almost precisely with others by Mr. Drew, made before mine but which I had not seen.

The secret of this success was in using a small diaphragm of three inches or less; between two and three inches seems to be the proper size. That this should be so is perfectly reasonable because the "air-waves" having an average size of one to four inches, have less "confusing" effect on a small than on a large aperture; and the extra light can so well be spared that an almost certain cause of many previous failures has been the excessive brilliancy of the disk. Thus I anticipate that not only do these observations come within reach of the amateur but the professional astronomer himself, to attain success, must return to some small instrument, perhaps to the usually despised and neglected finder at the side of his great tube.

A. E. DOUGLASS.

To The Editor of Popular Astronomy:—

It seems desirable to correct a statement contained in the last issue of Popular Astronomy.

My resignation from the Lick Observatory takes effect at the close of the present month, and not one year hence, as stated in the May number of Popular Astronomy.

The regents of the University of California urged me to withdraw my resignation and, as you stated, offered me a year's leave of absence with full pay, but I could not accept their kind offer as I feel satisfied that my present course is the proper one for me to take.

In justice to Professor Keeler I desire to say that had the Regents elected any other man for director my action would have been exactly the same.

Sincerely Yours,
J. M. Schaeberle.

University of California,
Mount Hamilton, May 11, 1898.

V Hydræ and 277 in Birmingham's Catalogue.–Two Crimson Stars. Those stars in which red is the predominating color even in a steady atmosphere are of especial interest on account of their great rarity and the uncertainty as to the cause of their distinctive glow. Two such orbs are now visible in the evening sky, the brightest being V Hydræ in R. A. $10^h\ 46^m\ 17^s$,, Decl. $-\ 20°\ 40'$. It is in the west point of a triangle formed with α and β *Crateris*.

Since the beginning of April it is of an unmixed crimson hue, but has been described as pale crimson, copper red and intensely red by reliable observers in the past. At present it is of about 7th magnitude. It is recorded as varying from 6th to 9th magnitude, and is accredited with a period of about 575 days by Gould, though according to the recent data of the "Companion to the Observatory" its period is 653 days.

If this latter data be correct, and the variation regular, the maximum will be due in the middle of August. According to Birmingham and other authorities stars of this class reserve their deepest tint for the minimum stage paling as they grow, and a decline in its crimson hue is then probable during the coming months.

The spectrum, no doubt observed at maximum, is described as being of the 4th type with strong lines in the red and green.

A nameless star in Virgo, the color of which was first noticed by Bessel in 1823, is also remarkably free from the yellow light that predominates in the greater number of reddish stars except when they flicker.

In Birmingham's catalogue of red stars it is numbered 277, in Schiellerup's, 145, and being in R. A. $12^h\ 19^m\ 37^s$ Decl. $+\ 1°\ 22'$, may be found about 2° northeast of η *Virginis*.

Fitly classed as crimson or red by many observers, it is recognized as variable with a range in magnitude from 6½ to 8½, though its period seems to be unknown. In fragmentary series of observations during the spring months of the last 5 years amounting in all to about 40 estimates, I have failed to detect any change greater than from about 7½ to 8th magnitude.

Spectroscopists class it as of the 4th type; and as the spectrum terminates in the green this interesting orb may have a dense atmosphere that obstructs the radiation of all violet light.

Rose O'Halloran.

San Francisco, May 14th, 1898.

Observations of *o* Ceti.*

1898

Jan. 3d. The variable is nearly as bright as *o* Ceti.

Jan. 9th. It is equal to ξ Piscium.

Jan. 19th. Not as bright as ξ Piscium but brighter than the adjacent stars, namely 66, 70, 71 and 75 in the constellation Cetus.

Jan. 21st. Equal to 75.

Jan. 28th. Equal to 70.

Feb. 4th. Brighter than 71.

Feb. 18th. Equal to 71.

Feb. 21st. Slightly dimmer than 71.

Feb. 28th. About half a magnitude dimmer than 71. At this date when the variable was of less than 7th magnitude observations were discontinued. The entire series, of which only an abstract has been given, extended from August 20, 1897 to February 28th, 1898 and included 87 nights when estimates of relative brightness could be satisfactorily taken. As is usually the case with this variable the process of decline was far slower than that of increase especially in the later stages.

ROSE O'HALLORAN.

San Francisco, May 20th, 1898.

Measures of the Satellite of Neptune.—E. E. Barnard of Yerkes Observatory has recently published an article in the *Astronomical Journal*, (No. 436), giving a series of measures of the position angle and distance of the satellite of Neptune by the aid of the 40-inch refractor. In this article Mr. Barnard gives interesting information concerning the recent work with the great telescope. The eye-pieces were made by Steinheil, of Munich. The following table of them will interest our readers:

No.	Eye-pieces, Magnifying power.	Diameter of Field. ″
1	230	396
2	280	395
3	350	376
4	460	240
5	700	153
6	940	116
7	1340	64
8	1700	53
9	2080	—
10	2680	33
11	3750	28

Stonyhurst College Observatory favors us with a report of the results of meteorological and magnetic observations for the year 1897.

Catalogue of Mathematical and Physical Sciences.—Parts I and II of Messrs. William Wesley & Son, London, England, 1898. These catalogues give full list of books and papers on comets, meteors, eclipses, photography, spectrum and the telescope.

* Continued from No. 51, page 56.

The May Atlantic Monthly contains an important article entitled Great Explorers of the Southern Heavens by Dr. T. J. J. See.

Solar and Terrestrial Magnetism is the title of a pamphlet of 176 pages recently prepared by Professor Frank H. Bigelow of the department of Meteorology, Government Weather Service, Washington, D. C. The pamphlet is illustrated and is prepared in the usual careful way that Professor Bigelow does his scientific work.

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